Towards Decentralised Energy Systems

An Analysis of the Distribution of Tasks to Safeguard Essential Energy Sector's Public Values

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An Analysis of the Distribution of Tasks to Safeguard Essential Energy Sector's Public Values

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Acknowledgements

Nicola Yoon, "Everything's a risk. Not doing anything is a risk. It's up to you".

Two years ago, I decided to take a small break from my hectic life as an engineer to see what's out there. Two years later, here I am writing acknowledgements for my thesis report, concluding my journey as a student. These past two years, I learnt a lot, fought my way through courses that I was not familiar with, and tried a wide variety of exciting activities. And I am thankful for all those experiences.

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Executive Summary

In the Netherlands, recent technological innovations have opened up opportunities to a more decentralised and low-carbon community energy system, allowing small-scale energy producers to distribute their excess energy and actively take part in the electricity market. This transformation leads to the emergence of decentralised energy systems in order to facilitate the integration of diverging energy sources into the existing power system. Nonetheless, the current energy system was built on a centralised manned or energy production and is not suitable for decentralised energy generation. Particularly because the shift towards decentralised energy systems entails a numerous new emerging tasks which put the protection of public values at stake.

Since the regulation of decentralised governance is currently underdeveloped, it remains unclear how these tasks can be distributed among actors in order to safeguard public values. Although some studies have pointed out that new emerging tasks are needed to be taken into account in the realisation of public values, there is a lack of scientific knowledge about how the distribution of tasks to safeguard public values is conceptualised and whether the distribution of tasks is able to contribute to the protection of public values. Adhering to those insights, the aim of this research is to explore the application of the distribution of tasks to safeguard essential energy sector's public values based on a plausible scenario of decentralised energy systems. Combined with the lack of knowledge on how the distribution of tasks safeguards essential energy sector's public values, the following research question is addressed in this research:

> How can the distribution of tasks among key actors be adapted to safeguard essential energy sector's public values in decentralised energy systems?

In the quest of answering this question, four subjects are addressed in this research. The first one concerns the conceptualisation of the distribution of tasks to safeguard public values in order to guide the analysis of the problem at hand. The second one focuses on a scenario of decentralised energy systems as a mean to study the distribution of tasks to safeguard public values. Following the conceptualisation of the analytical framework and the scenario of decentralised energy systems, the next step centers around the application of the analytical framework on the selected scenario. Lastly, unresolved issues surrounding the application of the distribution of tasks to safeguard public values are explored.

Building an Understanding of the Distribution of Tasks to Safeguard Public Values

This research's insights are built around three primary concepts—the distribution of tasks, public values, and safeguard public values—that are adapted from a wide range of theoretical grounds. The interactions between these key concepts are used to analyse the distribution of tasks to safeguard essential energy sector's public values.

First, the distribution of tasks means ensuring that tasks are appropriately assigned according to efficiency, effectiveness, and equity. Here a task is identified based on the conceptualisation of public values. Deriving from this definition, the conceptualisation of the distribution of tasks is based on two primary actors' attributes—role and resources. In the context of this research, the focus is on key fundamental roles that must exist in order to ensure the functionality of the decentralised energy systems. There are seven fundamental roles identified: producer, balance responsible party, system operator, grid operator, supplier, prosumer, and an additional role that emerges as a result of energy system change, i.e., Energy Service Company (ESCo). Meanwhile, resources relate to the practical means that actors have to realise their role(s).

Public values refer to essential public convictions that are to be achieved by public policy. Accordingly, there are two primary characteristics of the public values: (1) public values are the values shared by the society as a whole, and (2) public values require the state's involvement for their protection and realisation. In this research, the focus is on public values that are essential in the Dutch energy sector. Those values are security of supply, environmental sustainability, affordability, procedural justice, distributive justice, autonomy, and data privacy and security. The conceptualisation of each public value is used as the basis for tasks identification in decentralised energy systems.

The last concept binds the two preceding concepts. Safeguard public values implies that public values are successfully realised or protected. Therefore, the distribution of tasks safeguards public values when actors are able to successfully discharge assigned task(s) associated with the realisation or protection of public values.

A Scenario of Decentralised Energy Systems

By means of qualitative scenario planning, a scenario of decentralised energy systems is constructed based on the current trends in the Dutch energy systems. The proposed scenario is called the Plasma scenario. The Plasma scenario explores future decentralised energy systems where the integration of renewable energy generation is driven by societal attitudes towards sustainability, self-sufficiency, and more control over energy supply. Combined with the declining costs of renewable technologies as well as grid advancements, solar panels, energy storage, and load management become prevalent in society. As a result, new actors emerge to provide new services in order to accommodate consumers' demands while promoting efficient allocation of resources by capitalising on underutilised assets. These new entrants are accelerating the developments of technological innovations to support decentralised energy systems by facilitating the growth of "virtual" energy communities. As a result, new services emerge to substitute the conventional way of energy procurement, allowing consumers to select a mix of predominantly green energy to satisfy their electricity needs. This section elaborates upon the era of "virtually connected" energy communities in which individuals are able to directly communicate with each other to maximise the use of their excess assets.

The Plasma scenario offers autonomous decision on energy trading and balancing services allowing participants to capitalise on their distributed assets. Furthermore, the Plasma scenario allows each member to set their own preferences with regard to their assets or energy mix—thus promoting freedom of choice. Therefore, participation in energy services is not obligatory and emphasises on the free participation of individuals who are willing to buy and sell energy products. New actors and services emerge to support the operation of the Plasma scenario. At an individual level, the transition towards decentralised energy systems has resulted in the social transformation of end-users from energy consumers to prosumers. Meanwhile, independent service providers materialise to facilitate the provision of energy services such as energy trading and balancing services. Although this scenario is developed to enable more control over energy supply and self-sufficiency, it does not imply that incumbent actors cease to exist. Instead, they operate in parallel with this new system to support the operation of the Plasma scenario. An illustration of this scenario is represented in Figure 1.

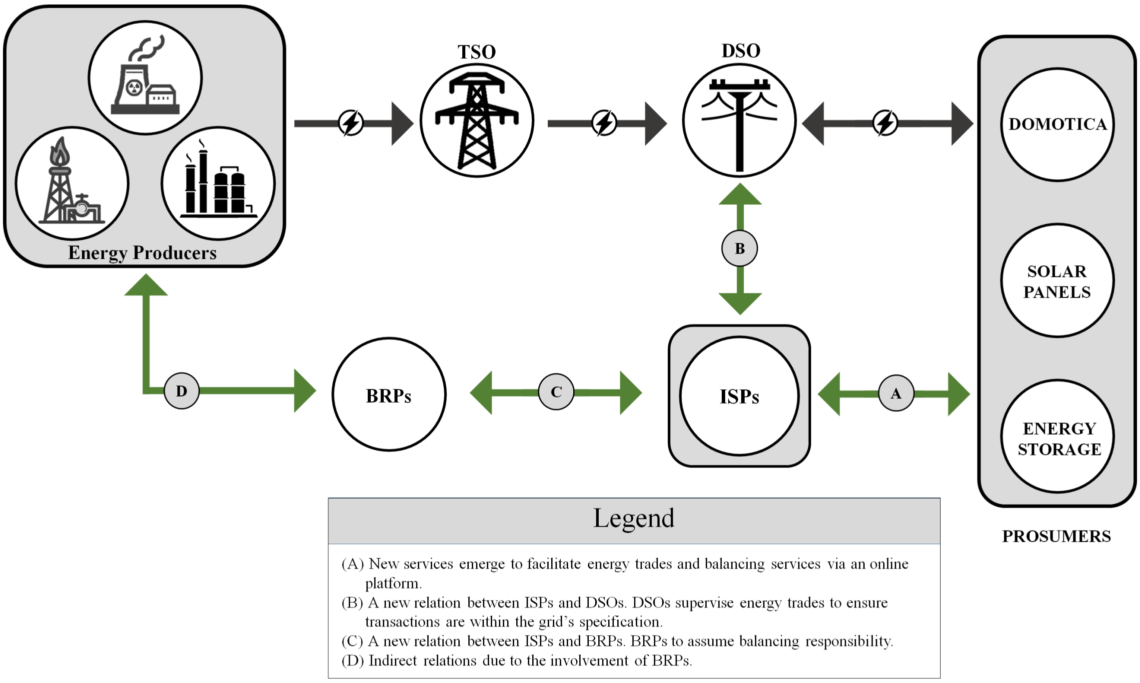

Figure 1: Illustration of key actors' relations in the Plasma scenario.

Based on the scenario presented in the previous section, the emergence of independent service providers replace the need for conventional energy suppliers. Accordingly, these actors assume multiple roles such as energy supplier and Energy Service Company (ESCo). As the ESCo, ISPs do provide not only online trading platforms for their members but also technical artefacts used to support the functionality of the systems. Meanwhile, traditional actors such as Distribution System Operators (DSOs), Balance Responsibility Parties (BRPs), and (indirectly) centralised energy producers still exist to support the functionality of the decentralised energy systems. Particularly because the distribution of electricity is executed via the distribution network and the requirement for balancing responsibility. The analysis focuses on new relations that emerge in decentralised energy systems (represented as green line in Figure 1.

The Distribution of Tasks to Safeguard Public Values

By applying the analytical framework on the selected scenario, the outcomes show that the application of the distribution of tasks results in a centralised manner of tasks allocation. In this particular case, it can be justified that the centralisation of public values among these two actors is caused by their roles and resources supporting the goals and functionalities of decentralised energy systems. Additionally, the operation of decentralised energy systems that utilises the existing grid infrastructure creates interrelated tasks among actors to realise public values. These tasks jointly build up the functionality of energy trading and thus decentralised energy systems. As a consequence, the realisation of public values from one actor depends on how the other actor fulfils their specific tasks. Those conditions lead to value conflicts because actors are responsible for multiple values or multiple actors are responsible for a certain public value, affecting the realisation of public values. Since the concept of "safeguard public values" implies successful realisation or protection of public values, government's interventions are required in order to safeguard public values, known as "residual responsibility".

Unresolved Issues

According to the analysis, many unresolved issues arise in relation to the use of the distribution of tasks to safeguard public values. These issues are categorised into three overarching aspects in order to provide clarity. First, changing roles and resources of actors implies a need for mobilising capabilities (resources) in decentralised energy systems. Therefore, there are two main aspects required: (1) facilitating possible transfer of role(s) and resource(s) between actors in the systems, and (2) establishing agents to define and facilitate such changes. Since the distribution of tasks is based on actors' roles and resources, those two factors are considered important to ensure that actors' are able to discharge the assigned tasks in order to realise or protect public values.

The second point concerns the need for specification. The identification of tasks that is based on the conceptualisation of public values, shed some light on the need to clarify the public value outcomes to be achieved. This term means at which level public values are expected to be safeguarded. This aspect is particularly important because the involvement of new emerging actors in the systems with a varying degree of resources. These diverging resources lead to the second factor in this aspect, specifying actors attributes for the assignment of task(s) associated with public values. Here it implies that there should be thresholds in which actors are held responsible for a certain task—or even assume a certain role.

Third, by including the government in the realisation or protection of public values, some issues may arise depending on the extent of intervention. First, how to balance between the level of abstraction and specification in government interventions. Second, how to ensure that the government's interventions achieve the desired outcomes for society as a whole.

Conclusion

By taking into account the outcomes of the analysis as well as identifying some unresolved issues presented in the previous sections, the answer to this main question lies in understanding the conceptualisation of the key concepts used in this research—the distribution of tasks, public values, and safeguard public values. The distribution of tasks is operationalised by considering two primary attributes of actors in the systems—roles and resources— to achieve efficiency, effectiveness, and fairness. Therefore, an understanding of the role(s) and the exact resources required to realise the role(s) are imperative. Nevertheless, a shift towards decentralised energy systems may indicate transferring of roles and resources. This factor should not be undermined and must be facilitated to ensure that actors can discharge the assigned tasks in order to realise or protect public values. Additionally, there is a need to specify at which level each actor is responsible for each task that is assigned to them in order to realise or protect corresponding public value. In other words, specifying actors' attributes for tasks allocation and elucidating the outcomes to be achieved for each actor depending on the resources they have. These aspects are important because new actors that emerge in the system carry different levels of resources, which indicate different levels of capacity to assume task(s). However, it is worth noting that by specifying the required resources and outcomes to be achieved, there is a possibility of exclusion, which may lead to debate. Therefore, there is a need to find a balance between these two aspects. Lastly, by increasing the state's interventions through regulatory frameworks, access to capital and financing, as well as facilitating public values trade-offs, a leitmotiv can be developed that further improve the application of the distribution of tasks to safeguard public values.

Recommendations

The analysis of the distribution of tasks to safeguard essential energy sector's public values conducted in Chapter 4 and Chapter 5 reveal gaps in the formal regulatory as well as the analytical frameworks that need to be addressed in order to support the growth of decentralised energy systems. This section puts forward recommendations based on two different perspectives, the development of decentralised energy systems and the use of the distribution of tasks to safeguard public values.

Recommendations for the development of decentralised energy systems

1. The emergence of new actors without sufficient resources to undertake any fundamental role(s) may hinder the development of decentralised energy systems due to many factors. From the economic perspective, the involvement of such actors results in large interdependencies to the incumbent actors that may negatively impact the economic feasibility of the systems. Accordingly, it is imperative to ensure that actors involved in the development of decentralised energy systems have sufficient resources to assume role(s).
2. The current regulatory frameworks that are used as safeguarding mechanisms in the Dutch energy sector may hinder the realisation of decentralised energy systems. This situation emerges because the development of decentralised energy systems goes hand in hand with the developments of technological innovations in the energy sector. For example, the *Salderingsregeling* which restricts the growth of energy storage at the end-user level. Accordingly, these regulatory frameworks should be adjusted in order to support the development of decentralised energy systems.
3. Regulatory frameworks shall not limit the ability of incumbent actors to utilise available technologies in order to safeguard public values, supposing that the adoption of these technologies does not harm the stability of the market or conflict with their monopoly role in the electricity system.

Recommendations for the use of the distribution of tasks to safeguard public values

1. The use of distribution of tasks to safeguard public values requires a deeper understanding of not only the roles and resources actors have but also their drivers and how these drivers affect the management of their resources. Therefore, socio-economic characteristics of each actor should be taken into account if resources are used as a ground for distributing tasks.
2. The conceptualisation of the distribution of tasks that are used to achieve efficiency, effectiveness, and equity contradicts the idea of decentralisation as tasks are centrally distributed, resulting in many value conflicts. Therefore, there is a need to expand the concept of the distribution of tasks in order to achieve desired outcomes.
3. A quantification of public values may be required in order to assign a certain task(s) to actor(s) in decentralised energy systems. This specification is required to ensure that actors have required resources to discharge the assigned tasks, which in turn ensuring the realisation or protection of public values. Nevertheless, it is important to find a balance between the level of abstraction and specification to avoid inefficiency and exclusion.
4. Government interventions to safeguard public values should ensure that they achieve desired outcomes without negatively, affecting another part of society.

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Abbreviations

BRPs	Balance Responsible Parties
DSOs	Distributed System Operators
ESCo	Energy Service Company
ISPs	Independent Service Operators
TSO	Transmission System Operator

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Part One: Introduction

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1. The Grand Transition

In the Netherlands, growing awareness towards reducing CO_2 emission and dependence on fossil fuels have led to the rapid growth of renewable energy generation (Koirala, Koliou, Friege, Hakvoort, & Herder, 2016; Stedin & Energy21, 2018). As a result, the energy system is currently undergoing fundamental changes. First, the transition towards renewable energy generation leads to citizens active involvement in energy production and consumption. Second, a new demand emerges to enable the integration of this diverging energy generation on the grid (Koirala et al., 2016; Ongkiehong & SenterNovem EOS, 2006). In both cases, the transition towards renewable energy generation leads to a shift from a highly-centralised energy system to a more decentralised energy system. Nevertheless, the quest for sustainability is not smooth sailing. Decentralised energy systems frequently lead to adverse effects because the current energy system is not meant for decentralised energy generation. This chapter aims to provide the context of the research as well as its relevance from the literature and societal context. **Section 1.1** explains insights on potential challenges of decentralised energy systems that are central to the research. **Section 1.2** describes the academic and societal knowledge gaps addressed in the research to show the relevance of the study. Following the identification of research gaps, **Section 1.3** provides the research objectives and research questions. **Section 1.4** presents the scope of the study. Finally, this chapter is concluded with Section **Section 1.5**, which provides an overview of the upcoming chapters in the report.

1.1 A shift towards decentralised energy systems

A decentralised energy system is characterised by locating energy production facilities close to the place where it is used (Watson & Devine-Wright, 2011). Consequently, this concept implies that electricity is produced by means of small-scale renewable energy generators (hereinafter referred to as decentralised energy generation). The concept of decentralised energy systems is embraced by a multitude of actors due to its advantages. First, decentralised energy systems allow more control over resources and energy supply, reducing dependency on the main grid (Giotitsas, Pazaitis, & Kostakis, 2015; Kloppenburg & Boekelo, 2019) and thus removing the effects of speculative market mechanisms by centralised suppliers or distributors (Jogunola et al., 2017; Kloppenburg & Boekelo, 2019; Morstyn, Farrell, Darby, & McCulloch, 2018). Second, decentralised energy systems alleviate energy losses throughout the energy value chain (e.g., from generation to consumption) (Tushar et al., 2018). As a result, decentralised energy systems increase energy efficiency and minimise negative environmental and social impacts caused by fossil-fuelled power plants (Bouffard & Kirschen, 2008; Koirala et al., 2016). Third, decentralised energy systems improve resilience to disruptions—if one component collapses, it does not affect the entire power system (Giotitsas et al., 2015).

While decentralised energy systems are introduced of having positive traits, their developments may be contested because the current Dutch energy systems are still primarily based on centralised energy production and regulation of active participation is currently somewhat underdeveloped (see, e.g., Lammers & Diestelmeier, 2017). The following section demarcates challenges for the adoption of decentralised energy systems in the Netherlands, followed by societal problems addressed in the research.

1.1.1 New Emerging Tasks to Safeguard Public Values

In recent years, changes in societal attitudes towards climate change have motivated innovative governance approaches by private actors who bring opportunities and challenges. New actors such as prosumers[1] are slowly making their way to be actively involved in delivering energy services and contribute to the energy production via the ownership of distributed energy resources such as solar panels and energy storage (Koirala et al., 2016; Kooij et al., 2018; Leal-Arcas, Lesniewska, & Proedrou, 2018b). However, decentralised governance has not been materialised in the Netherlands (Lammers & Diestelmeier, 2017). Currently, prosumers, among others, do not have a clear function in the electricity system, since they are neither a supplier nor a generator (Lammers & Diestelmeier, 2017; Parag & Sovacool, 2016). As a result, it remains unknown how these new actors can contribute to the adverse effects caused by the integration of decentralised energy generation into the existing power system.

To illustrate, the growing number of small-scale producers connected to the grid has caused imminent problems for the grid operators as they have to deal with the unpredictable volume of locally generated electricity. Such an issue arises because the energy generated by renewable technology is stochastic by nature. It varies according to time, weather, and consumer behaviour, which at times are unpredictable (Koirala et al., 2016). As the grid operators have statutory tasks to safeguard energy sector's inherent public values such as security of supply, sustainability, and affordability (Bruijn & Dicke, 2006; M. Edens, 2017), there is a need to manage the fluctuations caused by renewable energy generation to ensure the security of supply. However, only a limited number of options are available within the boundaries of the existing regulation, and grid operators are unable to undertake any commercial roles in providing grid balancing as it may conflict with their monopoly characteristics in the power system (see, e.g., M. Edens, 2017; M. G. Edens & Lavrijssen, 2019; Lammers & Diestelmeier, 2017). As a consequence, grid operators may need to

[1]Prosumers are defined as proactive consumers who actively manage their own production and consumption of energy by the use of distributed energy resources (DERs) (Morstyn et al., 2018).

choose options that are not cost-effective such as grid reinforcement or secure a larger dispatchable reserve to ensure the reliability of the grid network. Such options may induce adverse effects on the affordability of the energy which affect the society as a whole (M. Edens, 2017; M. G. Edens & Lavrijssen, 2019; Ueckerdt, Brecha, & Luderer, 2015).

Deriving from the above exemplary case, multiple insights can be used to explain challenges with decentralised energy systems. First, the integration of renewable energy generation into the existing power system may put public values at stake as it contradicts the responsibility of the incumbent actors as the safeguarders of the energy sector's public values. In this particular example, public value conflicts[2] occur between sustainability and affordability. On the one hand, the ownership of distributed energy resources such as solar PVs promotes sustainability. On the other hand, the integration of renewable energy generation increases overall network costs which negatively affect the electricity prices putting more burdens on consumers (affordability).[3] These value conflicts are inevitable because the shift towards decentralised energy systems is not being followed by changing of energy policy and regulatory frameworks in the energy system (see, e.g., Lammers & Diestelmeier, 2017; Stewart, 2006).

Second, the adoption of decentralised energy systems entails the emergence of new tasks, which is problematic as they may have implications on the realisation of public values. According to the above example, incumbent actors are expected to safeguard public values such as security of supply, sustainability, and affordability. However, the integration of renewable energy generation carries new tasks for incumbent actors to ensure the realisation of public values. Within the current regulatory framework, incumbent actors such as grid operators are not assigned and equipped with the tasks of actively managing such fluctuations (Lammers & Diestelmeier, 2017). Furthermore, the current tasks allocation among actors to safeguard public values is still largely based on centralised energy production and is not suitable for decentralised energy systems (see, e.g., M. Edens, 2017). Combined with the emergence of new actors that are not yet defined in the current regulatory framework, it remains unknown how these new actors can contribute to the realisation of public values in the energy sector. Accordingly, new arrangements in the distribution of tasks among actors to safeguard public values may be required to facilitate the emergence of decentralised energy systems and eventually let such an initiative materialises.

In short, the adoption of decentralised energy systems may put public values at stake. This issue arises because the transition towards decentralised energy systems carries new tasks associated with the realisation of public values, raising questions about how these new tasks can be distributed among actors to safeguard public values. Nevertheless, defining tasks allocation among actors to safeguard public values is not a simple matter. The heterogeneity of actors involved in the energy system should be taken into consideration as they may attempt to influence the outcomes of the system according to their own interests by utilising resources they have (Blanchet, 2015). More importantly, the presence of numerous commercial and regulated entities as a result of privatisation and liberalisation of the Dutch's energy system have created complex and convoluted actor arrangements (M. A. Buth, Wieczorek, & Verbong, 2019). These actors may have different perspectives on the integration of decentralised energy generation into the existing power system, which call for different arrangements to safeguard public values. Accordingly, this leads to societal problems and persistent questions to be answered in the course of this research:

1. What are the challenges with the use of the distribution of tasks to safeguard public values in decentralised energy systems?

[2]A value conflict arises when "*(1) a choice has to be made between at least two options for which at least two values are relevant as choice criteria, (2) at least two different values select at least two different options as best, and (3) the values do not trump each other.*" (van de Poel & Royakkers, 2011, p. 177)

[3]An exemplary case of affordability issue is the adoption of "Energiewende" (or energy transition) in Germany. The implementation of such a policy induces high electricity prices resulting in "energy poverty" for certain parts of society (Fischer, Hake, Kuckshinrichs, Schröder, & Venghaus, 2016).

2. Can the distribution of tasks be used to safeguard public values in decentralised energy systems?

1.2 Research Gaps

Based on the above information, the distribution of tasks among actors to safeguard public values in decentralised energy systems becomes the centre of this research. Therefore, knowledge related to the use of the distribution of tasks to safeguard public values and consequences it entails are desired.

From a scientific perspective, Lammers and Diestelmeier (2017) and Heldeweg, Sanders, and Harmsen (2015) have addressed potential tasks that might emerge to safeguard public values due to the integration of decentralised energy generation into the existing power system. However, their studies did not further elaborate on how these tasks can be distributed to safeguard public values. Additionally, these studies also did not explicitly mention which new tasks, related to the realisation of public values, that might emerge as a result of transition towards decentralised energy systems. Nonetheless, both studies highlighted the need to redistribute tasks among actors in order to safeguard public values in decentralised energy systems.

In relation to the distribution of task, the scientific literature is also limited in providing an answer on how the distribution of tasks can be conceptualised to safeguard public values in decentralised energy systems. Studies in safeguarding public values are mainly found in the development of: (1) large-scale infrastructure projects such as Charles, Dicke, Koppenjan, and Ryan (2007) or Vuorinen and Martinsuo (2019), and (2) changes in public administration such as Charles et al. (2007) or Corrà (2014). Furthermore, recent scientific articles that discussed safeguarding public values in the energy sector are still mainly focused on the realisation of public values based on a single actor's perspective, which mainly emphasised on the grid infrastructure (see, e.g., Charles et al., 2007; M. Edens, 2017; M. G. Edens & Lavrijssen, 2019; Heldeweg et al., 2015). In another study, Steenhuisen (2009) focused on competing public values in heavily regulated sectors such as energy and transportation and how to cope with them. However, his study did not provide insights into the emergence of new tasks associated with decentralised energy systems and how the distribution of tasks can be used to safeguard public values. As a result of knowledge void in the scientific literature, there is a lack of understanding of analysing the application of the distribution of tasks to safeguard public values.

As seen in the above insights, there is no complete solution which could be found within the existing scientific literature for the problem at hand. Accordingly, the above information helps to define the knowledge gap of this research, which would be studied in the course of the research:

1. Some researchers have mentioned about possible emerging tasks associated with the realisation of public values. However, no available research focuses on how these new tasks can be distributed among actors to safeguard public values in the decentralised energy systems.
2. In relation to the first point, there is a knowledge gap on how the distribution of tasks to safeguard public values is conceptualised and analysed in decentralised energy systems.
3. There is no available literature on the challenges or consequences of using the distribution of tasks to safeguard public values.

Research Gaps

1. Conceptualising the analytical framework to study the distribution of tasks to safeguard public values in decentralised energy systems.
2. Exploring challenges and consequences with the application of the distribution of tasks to safeguard public values in decentralised energy systems.

1.3 Research Objective

The previous sections highlight the context of safeguarding essential energy sector's public values through the distribution of tasks and give further insights on the subject by delivering research gaps based on current scientific literature. According to the aforementioned discussion, some studies have addressed the importance of safeguarding public values in the wake of decentralised energy generation. However, these studies are limited to the existing grid infrastructure based on a single actor's perspective and did not take into account other key actors in decentralised energy systems. Nevertheless, those studies can be used as the basis for the identification of essential energy sector's public values. Additionally, other studies have addressed new emerging tasks that may appear due to the adoption of decentralised energy systems. Still, they did not provide explanations on how those emerging tasks could be distributed among actors to safeguard public values and eventually safeguard public values. Combined with missing scientific knowledge on how the distribution of tasks is conceptualised as well as the challenges it entails, these insights help to develop a relevant main research question and the sub-questions for this study. The main research question is formulated as follows:

> **Main Research Question**
>
> How can the distribution of tasks among key actors be adapted to safeguard essential energy sector's public values in decentralised energy systems?

In order to answer the main research question, a set of sub-questions, are formulated as follows:

Sub-question 1: How can the distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems be analysed?

The first sub-question focuses on building an analytical framework that can be used for the analysis and evaluation of the distribution of tasks to safeguard essential energy sector's public values. This section is imperative to guide the analysis of the proposed decentralised energy systems that will be formulated later on in this research.

Sub-question 2: What is a scenario of decentralised energy systems based on current trends and developments?

In order to study the distribution of tasks to safeguard public values, a possible scenario of decentralised energy systems is used as a means to study the distribution of tasks to safeguard essential energy sector's public values. Therefore, the objective of this sub-question is to build a possible scenario of decentralised energy systems.

Sub-question 3: How can the distribution of tasks safeguard essential energy sectors public values in the selectedscenario of decentralised energy systems?

This sub-question serves to analyse how the distribution of tasks safeguards public values in the selected scenario of decentralised energy systems. This is done by applying the theoretical framework proposed in the sub-question 1 on the selected scenario from the sub-question 2.

Sub-question 4: What are the unresolved issues in the use of distribution of tasks to safeguard essential energy sectors public values in decentralised energy systems?

This sub-question focuses on exploring unresolved issues that may arise with the use of the distribution of tasks to safeguard essential energy sector's public values.

1.4 Research Scope

Because of the complexity of the problem at hand, it is important to make a clear scope for this research in order to provide clarity. This section presents the scope of the research, which subjects are taken into account and which are not.

To start with, the scope of this research is bounded to a scenario of decentralised energy systems based on current trends and developments in the Netherlands. Additionally, it is important to mention that the scenario is built according to a limited number of drivers: (1) more control over supply, and (2) the need for self-sufficiency. Other assumptions and limitations applied to the selected scenario are presented in the corresponding chapter(s) and complied in Appendix A. Furthermore, decentralised energy systems come with many forms and variations. In the context of this research, decentralised energy systems focus on the generated electricity produced by small-scale producers (prosumers), which is distributed via the distribution networks. Therefore, the scope of this research is limited at the regional level.

The second scope relates to the development of an analytical framework. Multiple actors are involved in the adoption of decentralised energy systems. However, this research only focuses on actors that are deemed critical for the development of decentralised energy systems. The identification of critical actors is based on the operation of decentralised energy systems, which still utilises the existing distribution network to deliver electricity. This setting implies that the transactions within decentralised energy systems are conducted "virtually". The selection of these actors are presented in Chapter 2. A more elaborate identification of actors involved in the developments of decentralised energy systems is available in Appendix C. Furthermore, the public values used for the analysis are also limited to those of considered essential to limit the scope of the study (see, e.g., Charles et al., 2007). The selection of public values and the basis of this selection are provided in Chapter 2. Appendix B presents public values that are recognised in the literature.

Other aspects that are left out in this research are addressed in the corresponding chapter and subjected to future research. Meanwhile, all assumptions are reconciled in Appendix A in order to provide clarity of this research.

1.5 Thesis Outline

A brief overview of the report proceeds as follows. Chapter 2 continues with the development of an analytical framework used for the research. Chapter 3 provides an overview of the research methodology that is used for scenario planning and the identification of tasks. Chapter 4 presents a scenario of decentralised energy systems that will be used as means to study the distribution of tasks to safeguard public values. Chapter 5 analyses the distribution of tasks to safeguard public values in decentralised energy systems by applying the analytical framework proposed in Chapter 2 on the selected scenario presented in Chapter 4. Chapter 6 elaborates upon lessons and implications of the analysis. Chapter 7 provides conclusions of the study and recommendations related to the application of the distribution of tasks to safeguard public values. Lastly, Chapter 8 presents reflection of the research and provides directions for future research. Figure 1.1 presents an outline for the upcoming chapters.

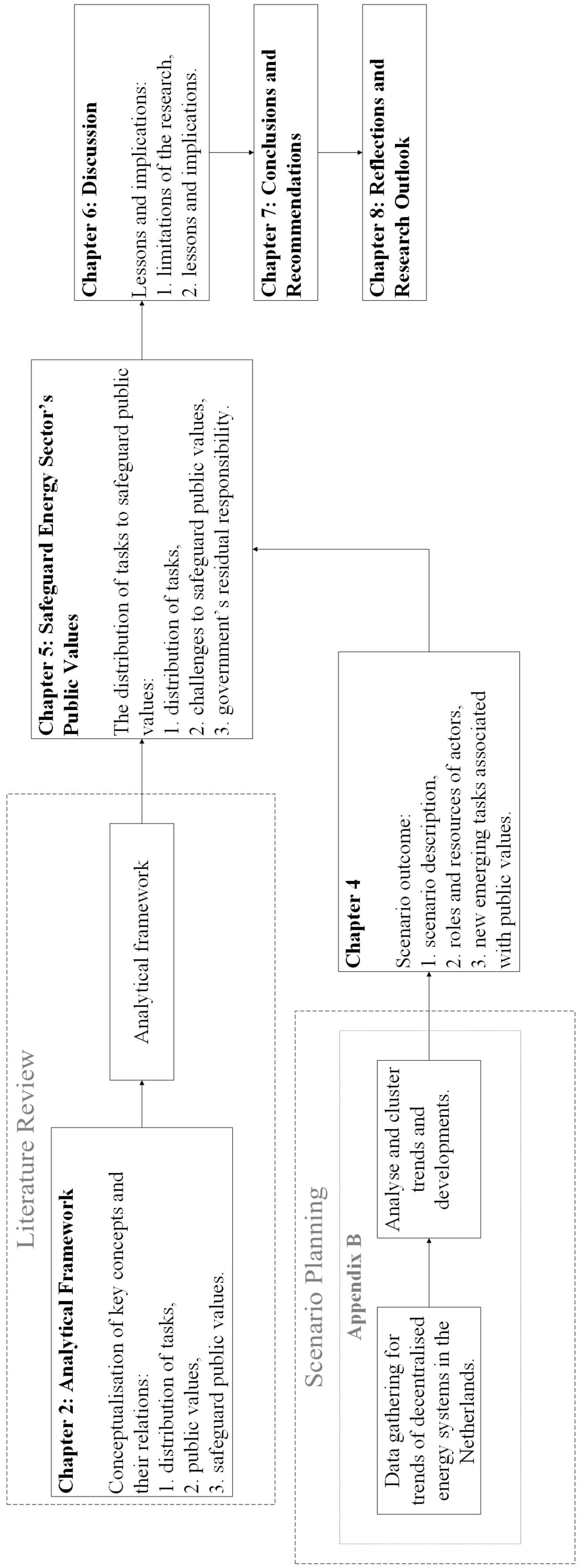

Figure 1.1: Thesis outline.

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Part Two: Positioning

2. Analytical Framework

In the previous chapter, research objective and research questions were formulated. In order to appropriately address the problem at hand, the goal of this chapter is to develop a theoretical framework based on multiple key concepts used in this research. Thus, this chapter provides an answer to the first sub-question:

How can the distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems be analysed?

The theoretical framework provides guidelines to analyse and evaluate the use of distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems. As the distribution of tasks occurs in the context of decentralised energy systems, the first section provides the definition of decentralised energy systems and how the key concepts relate to each other (**Section 2.1**). The second section focuses on the distribution of tasks as a vehicle to safeguard public values. Here a conceptualisation of distribution of tasks is presented (**Section 2.2**). The third section focuses on the second key concept which is energy sector's essential public values. Here a conceptualisation of public values is provided, followed by which public values are considered essential in the energy sector (**Section 2.3**). The fourth section relates to how distribution of tasks can be utilised to safeguard public values. Therefore, this section presents the theoretical foundation of the distribution of tasks and its conceptualisation (**Section 2.4**). By understanding those key concepts, the last part of this chapter contextualises the relationships between those key concepts to develop a theoretical framework that will be used to guide the analysis and evaluation of the distribution of tasks to safeguard public values in decentralised energy systems.

2.1 Decentralised Energy Systems

The following section provides the theoretical concept of energy systems found in the literature, followed by the relationship between key concepts used in this research and other elements in the systems.

Decentralised energy systems may be defined as systems that transform and store energy and are characterised by locating their facilities close to energy consumers (Watson & Devine-Wright, 2011). This application may consist of renewable energy sources such as solar panels, hybrid collectors, or wind turbines that are combined with various distribution technologies such as smart grids or power storage capabilities including power-to-gas or batteries (von Wirth, Gislason, & Seidl, 2018).[1] According to Ackermann, Andersson, and Söder (2001), the application of decentralised energy systems may vary depending on "*the purpose, the location, the power scale, the power delivery, the technology, the environmental impact, the mode of operation, the ownership, and the penetration of distributed generation*" (p. 196). As a consequence, a wide variety of decentralised energy systems are currently in use. Nevertheless, these systems can be identified based on the technical systems (both physical and information infrastructure), network of actors, and institutions (rules) that make up the systems (Geels, 2004; von Wirth et al., 2018). These aspects are used as the conceptualisation of the energy systems defined in this report.

Geels (2004) conceptualises the technical system as the linkages between different sub-functions that are necessary for the functionality of the systems. Adhering to this definition, the linkages between sub-functions can be represented as the relations between multidimensional layers in the energy systems. Following the composition of the energy systems proposed by de Vries et al. (2017), International Energy Agency (2018), and Bompard, Han, Masera, and Pons (2014), there are three different layers that make up the energy systems, physical, economic, and information layers. The physical layer refers to physical components such as electricity grids in which the electricity is flowing. The economic layer relates to the money flows caused by the transactions of electricity and other energy products. The information layer concerns information exchange in the systems that is used to support the delivery of energy services. Therefore, the technical system consists of physical artefacts, technological infrastructure, knowledge, capital, and labour, that support the functionality of the energy systems or known as resources (Geels, 2004).

Nevertheless, the technical system will not function autonomously. Actors are required to ensure the functionality of the technical system as they are related to resources and sub-functions in the systems (Geels, 2004). In this report, actors are defined as parties that are able to exert influence on a decision. To put it differently, actors are entities who have a certain interest in the systems and/or have some abilities to influence the outcomes of the systems (Enserink et al., 2010). Therefore, actors can be individuals, groups of individuals, firms, organisations, or parts of firms/organisations. Additionally, the activities of actors in the systems affect the use of resources and the linkages between different sub-functions (Geels, 2004). In the context of energy systems, the heterogeneity of actors should be taken into consideration as they may attempt to influence the outcomes of the system according to their own values and interests by utilising resources they have (Blanchet, 2015).

Although actors are able to influence the outcomes of the systems, they are not entirely free to act. According to Geels (2004), institutions (or rules) guide actors' perceptions and activities in the systems. Therefore, rules comprise of a multitude of practices, regulations, or laws that regulate the interactions and relations between actors to achieve a certain objective (Eaton, Meijerink, & Bijman, 2008; Edquist & Johnson, 1997). Depending on their functions, rules are able to: (1) provide information and reduce uncertainties, (2) manage conflicts and cooperation, (3) provide incentives, (4) channel resources to innovation activities, or (5) restrict technological innovations

[1] This research will only focus on solar panels as the main power generators for the decentralised energy systems.

(Edquist & Johnson, 1997). Consequently, different types of rules occur in the energy systems. This research does not focus on all rules associated to the energy systems, it rather only focuses on one particular subject, tasks allocation to safeguard public values.

To conclude, this section has provided the relationships between the subject of this study and other elements in the energy systems. There are three primary aspects that make up the energy systems, technical system, actors, and rules. Technical system refers to resources that support the functionality of the systems. Actors are those who have control of resources and are able to influence the systems. Meanwhile, rules govern the activities of actors in the systems. Consequently, there are many rules governing the energy systems. Nevertheless, this report only focuses on a part of the rules which is the distribution of tasks to safeguard public values. The following section demarcates the key concepts used in this research, starting from the term distribution of tasks, public values, and the distribution of tasks to safeguard public values in the context of decentralised energy systems.

2.2 Distribution of Tasks

The shift towards decentralised energy systems marks a transition from hierarchical to a more network-based form for decision-making. In other words, the energy systems are slowing changing from a vertically integrated system to a more horizontally distributed manner, which implies that new private actors emerge in the energy systems. As a consequence, the transition towards decentralised energy systems slowly diffuses the boundaries between private and public actors (see, e.g., Jacobsson, Pierre, & Sundström, 2015; Mees, Driessen, & Runhaar, 2014). Such a transformation indicates that there is a shift from government to governance, which arises the need for new actor arrangements to address challenges caused by the transition (see, e.g., Graafland, 2003). Pedersen, Sehested, and Sørensen (2011) consider the distribution of tasks as an essential part of a shift from government to governance. Particularly when adverse external effects are being neglected by new private actors (Graafland, 2003; Pedersen et al., 2011), which is aligned with the background of this research.

In the context of public administration, the use of distribution of tasks (or known as tasks allocation) is to ensure that efficiency is realised (see, e.g., Benson & Jordan, 2008). Its rationale is derived from the key concepts of centralisation vs. decentralisation. In a centralised system, tasks are often centralised and distributed across a number of central actors under which centralisation is appropriate, i.e., economically efficient. The same rationale has been used in the energy systems. To illustrate, the Dutch electricity system was built upon centralised manner to accommodate centralised energy production (Stedin & Energy21, 2018). Such a system was developed because it induced efficient resources allocation and generated substantial economies of scale to ensure the reliability of the energy system (Klaassen, 2016). However, transition towards decentralisation implies that new actors emerge in the systems, which may negatively impact the efficiency of the systems due to the emergence of additional tasks associated with public values (See Chapter 1). Consequently, decentralisation calls for a new arrangement of the distribution of tasks among actors in the systems, which indicates changing of actors arrangements in the systems (see, e.g., Benson & Jordan, 2008).

While the distribution of tasks is required in a decentralised setting, it is essential to understand that the current actor arrangements are structured formally and characterised by their stability and, therefore, predictability (see, e.g., Edquist, 2004; Goodin, 1998; Koppenjan & Groenewegen, 2005). Therefore, they are hard to change. Particularly in an environment with large interdependencies like the energy sector where a multitude of actors are involved in the delivery of energy products and services. Accordingly, efficiency should not be the only factor to determine the distribution of tasks as it is not without consequences. In Martens, Mummert, Murrell, Seabright, and Ostrom (2002), the distribution of tasks based on efficiency can induce "the costs of delegation" which falls into two categories. First, moral hazards. In the events of actors cannot efficiently commit tasks assigned to them, they may be exposed to undesirable risks. Second, information rents. This type of cost implies that without the right incentives, actors may exaggerate the "hardships" that they particularly face due to the assignment of tasks. Furthermore, distribution of tasks based on efficiency may lead to a centralised manner of actor arrangements as efficiency means to take the shortest route towards the fulfilment of the desired goals (Manzoor, 2014). Consequently, efficiency by itself is insufficient. Charbit (2011) suggests that any new actor arrangements related to decentralised governance should also include effectiveness and equity. This objective is similar to those of the distribution of responsibilities mentioned in Doorn (2020). Accordingly, the distribution of tasks implies that tasks allocation between actors in the systems are conducted based on not only efficiency but also effectiveness and equity.

2.2.1 Conceptualising Distribution of Tasks

Now that the concept of distribution of tasks is established, the next question is how to operationalise the distribution of tasks among actors. Since the objectives of the distribution of tasks similar to those of the distribution of responsibility, this research utilises similar approach to identify which attributes of actors can be used to allocate tasks based on efficiency, effectiveness, and equity. According to Doorn (2020), there are many grounds for assigning tasks. However, only two attributes will be used for the study, i.e., role and resources (capacity). These attributes are selected because of three reasons: (1) this research is closely related to the governance, (2) as described in the Chapter 1, these two grounds have been the primary discourses of the development of decentralised energy system (see Leal-Arcas, Lesniewska, & Proedrou, 2018a; Masson et al., 2014), and (3) the concept of the distribution of tasks that aims to achieve efficiency, effectiveness, and fairness. The following section delineates each attribute by providing its definition and scope.

Firstly, role is selected because new actors (currently) do not have specific roles defined by formal rules. Additionally, role is selected because it is efficient to assign task(s) based on a role (Benson & Jordan, 2008). At the present time, current incumbent tasks are bound to specific roles mandated by the law. However, the absence of formal roles for new emerging actors may potentially put public values at stake. Since tasks follow from an actor's specific role (see, e.g., Doorn, 2020); therefore, it is important to distribute tasks based on actors' role(s). Here a role describes interactions with other parties in relation to a given business transaction (ENTSO-E, 2015). It indicates that actors carry out their activities by performing roles such as system operator or trader. Additionally, it is important to emphasise the differences between a role and an actor. As mentioned previously, an actor is an entity that is able to exert influence on a decision. This entity participates in a business transaction in which an actor assumes a specific role or a set of roles.

Secondly, the value trade-off is related to the issues of actors' resources. These resources can include financial, time, knowledge, physical, or even human resources (Coventry, Fisher, Kenning, Bee, & Bower, 2014; Doorn, 2020; Geels, 2004). In the case of energy transition, the ownership of resources is essential because the domination of incumbent actors is proportional to the resources they have. With possible integration of decentralised energy generation, it is imperative to identify which resources these new emerging actors have in order to safeguard public values. Additionally, resource or capacity is selected because of its effectiveness and fairness. The former notion implies that it is easier to assign task(s) for safeguarding public values to those who have the resource to do it. This is certainly important in the energy sector due to existing regulation that emphasises on the uninterrupted of the energy supply. Meanwhile, the latter indicates that it is unfair to assign task(s) for safeguarding public values for those who do not have the means to do it (Doorn, 2020).

In this research, resources are the practical means that actors have to realise their role(s). Coleman (1994) defines resources as things that actors can control and in which they have some interests to influence the outcomes of the systems. The ownership of resources enables actors to affect the system including other actors, relations, and rules (Enserink et al., 2010). As a result, the relations between actors and resources are control and interest. The notion of control and interest is of importance as it effects the system's outcomes. If actors have a full control over resources that interest them, their actions are predictable: they exercise their control over resources to align with their own interests. Nevertheless, the energy system is considered as a complex socio-technical system (Geels, 2004; Markard, Raven, & Truffer, 2012). It comprises of complex interrelated and dependencies between a wide variety of elements that make up the system. As such, actors are oftentimes not fully in control of resources that are involved in activities to satisfy their interests. Rather other actors may partially or wholly control their own resources (see, e.g., Coleman, 1994).

Now that the conceptualisation of the distribution of tasks is established, it is important to define the concept of task used in this research. A review of the literature shows that there is no definitive definition of task. Instead a task is conceptualised as a key variable in explaining the existence of some form of a concept (see, e.g., Painter, Burns, & Yee, 2010; van Thiel & Yesilkagit, 2014; Verhoest, Roness, Verschuere, Rubecksen, & McCarthaigh, 2010). Since the distribution of tasks is linked to the protection or realisation of public values, it can be safely assumed that a task is identified based on the conceptualisation of public values.

2.2.2 Essential Roles in Decentralised Energy Systems

According to Section 2.1, decentralised energy systems still utilise the existing grid infrastructure to distribute electricity; therefore, the delivery of electricity is still executed in the grid networks. Meanwhile, transactions between actors within the systems are conducted "virtually" as opposed to the traditional way of procuring electricity. Deriving from this definition, a few fundamental roles of actors that are required to ensure the functionality of the physical electricity delivery are still required. In essence, six fundamental roles exist to ensure the functionality of the energy system: (1) **producer**, (2) **balance responsible party**, (3) **system operator**, (4) **grid operator**, (5) **supplier**, and (6) **consumer** (de Vries et al., 2017; Universal Smart Energy Framework, 2015). Meanwhile, an additional role may emerge to support the adoption of decentralised energy systems. For example, by providing means to connect virtually. This new role is known as **ESCo (Energy Service Company)** (Universal Smart Energy Framework, 2015; Verkade & Höffken, 2018). In this research these roles are of great importance and used for the analysis. Actors will assume role(s) based on the interactions with other parties according to the proposed scenario of decentralised energy systems that will be formulated later on in this research. A short explanation for each role is presented in Appendix D.2.

2.2.3 Conclusion

To sum up, this section provides a conceptualisation of the distribution of tasks employed in this research. The distribution of tasks means ensuring that tasks are appropriately assigned based on efficiency, effectiveness, and equity. Accordingly, the conceptualisation of the distribution of tasks is based on two primary actors' attributes—role and resources.

2.3 Public Values

The concept of public values is widely used in a variety of subjects such as philosophy, economic, or sociology, and predominantly address something that is worth striving for (Dietz, Fitzgerald, & Shwom, 2005; Ligtvoet et al., 2014; Nabatchi, 2012). Similar to other terms used in social sciences, "public values" does not have a definitive definition. Consequently, depending on the context of study, public values can have different meanings (see, e.g., Rhodes & Wanna, 2007). This section will not address these different perspectives rather address public values from the perspective of public administration, followed by the definition of public values used in this research.

2.3.1 Conceptualising Public Values

A general approach to define public values is based on the notion that the protection of public values benefits the society as a whole in contrast to private values, which only benefits individuals or specific groups (Charles et al., 2007). A more specific definition of public values is given by Bozeman (2007), he defines a society's public values as "*those providing normative consensus about (a) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled; (b) the obligations of citizens to society, the state, and one another; and (c) the principles on which governments and policies should be based*" (p. 13). Accordingly, public values are the social standards, ideals, and principles to be achieved and sustained by the state through public policy.

Another polarity of in the definition of public values is related to the distinction between legal-normative and stakeholder approaches. The former is based on the idea that public values are rights that should be provided by the government and individuals should also have possibility to legal procedures should these rights be infringed upon. Therefore, this approach emphasises public values as universal, objective, and absolute. More importantly, public values should be safeguarded by means of laws and regulations (Charles et al., 2007). The latter views public values as a result of interactions between actors. These public values are formulated, reinforced, and embodied in the society via democratic processes which are susceptible to political debate and a shift in content (Charles et al., 2007; Jørgensen & Bozeman, 2007).

From those different approaches on public values, there are two commonalities. First, public values do not reside within individuals rather they have a public characteristic. It means public values are values shared by the society as a whole. These values are considered essential for the society and, therefore, the protection of these values is required. Second, public values require the state's involvement for their realisation. In this research the state refers to the government and other public organisations in the energy sector. The involvement of state implies that public values cannot be solved and conducted by the society itself. They depend on the government for the protection and realisation of those public values.

Additionally, it is important to mention that public values in this research are public values that are essential in the current energy sector (see, e.g., Charles et al., 2007). This scope is essential because actors are restricted and formed by the cultural and organisation characteristics of a specific sector. Therefore, perceptions of public values are sector, culture, and time specific. To illustrate, public values in the energy sector may be categorised as private values in the water sector (see, e.g., Charles et al., 2007; van Gestel, Koppenjan, Schrijver, van de Ven, & Veeneman, 2008).

2.3.2 Essential Public Values in the Energy Sector

According to the definition of public values used in this research, public values can be categorised into two primary clusters, substantive public values and procedural public values (Bruijn & Dicke, 2006; Charles et al., 2007; Williams & Shearer, 2011). Substantive values describe society's expectations regarding the performance of products or services (M. Edens, 2017; Williams & Shearer, 2011). Meanwhile, procedural values refer to how procedures or actions are conducted in order to achieve certain targets (Bruijn & Dicke, 2006; Ingrams, 2019). In the context of the energy sector, substantive values are public values that are considered as properties of utility services. Meanwhile, procedural values seek to enhance the quality of the decision-making process (Bruijn & Dicke, 2006; Charles et al., 2007; Dignum, Correljé, Cuppen, Pesch, & Taebi, 2016; M. G. Edens & Lavrijssen, 2019). The following section identifies essential public values in the energy sector based on these two categorisations.

The main idea of the substantive values is to describe public expectations with regard to the performance of utility services (Bruijn & Dicke, 2006; M. Edens, 2017; Steenhuisen, Dicke, & de Bruijn, 2009). These values are generally reflected in the regulatory frameworks which imply that the government is responsible for the protection of the substantive values (Bruijn & Dicke, 2006;

Dignum et al., 2016). Steenhuisen et al. (2009) consider such values as "soft public values" because of their distinct characteristics. First, these values have low visibility. It means that a sense of urgency is immediately created in the event of their "failures". To illustrate, when the lights go out, security of supply will rise in priority. Second, these values are difficult to operationalise. Public values that are represented in norms or counts are hard to measure. In the context of the energy sector, values such as sustainability can be an example. Different actors may employ different strategies to achieve what is desired inducing conflicting interpretations of what is accepted. Third is the low enforceability. Values such as sustainability cannot be implemented accurately without a clear definition. As a result, this value might appear hard to enforce. Fourth, there is long term orientation. Values that concern future generations may face risks of delay. Primarily because it may directly impact the current generations; therefore, such values may have a harder time to gain support (e.g., large investments required for sustainability measures). As these values are hard to pinpoint and objectivise, the last characteristic is contested.

Based on the above explanation, the first cluster of public values can be derived from the existing energy policy and regulatory frameworks that have been governing the energy sector (Bozeman, 2007; Bruijn & Dicke, 2006; M. Edens, 2017; M. G. Edens & Lavrijssen, 2019). In total, there are three substantial public values reflected in the energy sector, i.e., security of supply, environment sustainability, and affordability (see, e.g., Ministry of Economic Affairs, 2016). **Security of supply** refers to promoting a low-risk of interruptions in power supply and, therefore, ensure the availability of electricity (Demski, Butler, Parkhill, Spence, & Pidgeon, 2015; M. G. Edens & Lavrijssen, 2019; Künneke, Mehos, Hillerbrand, & Hemmes, 2015; Ligtvoet et al., 2014). **Environment sustainability** concerns a system which allows contribution to the climate goals through the reduction of greenhouse gas (GHG) emissions, promotes energy efficiency, and allows the integration of renewable energy generation into the existing power system in order to preserve environment for current and future generations (Milchram, de Kaa, Doorn, & Künneke, 2018). **Affordability** relates to the provision of energy that is as low as possible (Bruijn & Dicke, 2006; M. Edens, 2017; Milchram, de Kaa, et al., 2018).

On the other hand, the procedural values deal with public values that can enhance decision-making process in the energy sector (Bruijn & Dicke, 2006; Dignum et al., 2016). Such values relate to the practices, rules, and regulations that constitute decision-making processes. In Charles et al. (2007), procedural values can also be identified according to public values that are not adequately delivered by private sectors in the energy sector due to the absence of formal regulations. The primary concern of this cluster is to amplify *"citizenship, equity, justice, ethics, and responsiveness"* (Bruijn & Dicke, 2006, p. 719). There are a number of procedural values identified from the literature, i.e., procedural justice, distributive justice, autonomy, and data privacy. **Procedural justice** concerns the fairness in the decision-making process by giving all relevant stakeholders the opportunities to participate in the decision-making process (Demski et al., 2015; Dignum et al., 2016; Milchram, de Kaa, et al., 2018; Milchram, Hillerbrand, van de Kaa, Doorn, & Künneke, 2018). **Distributive justice** refers to equitable and reasonable distribution and allocation of outcomes, such as public goods, opportunities, welfare and/or public burdens (negative effects) across individuals or groups in society (Demski et al., 2015; Dignum et al., 2016; Friedman, Kahn, Borning, & Huldtgren, 2013; Künneke et al., 2015; Ligtvoet et al., 2015; Milchram, Hillerbrand, et al., 2018). **Autonomy** refers to a system that enables its users to pursue their own goals and decide, plan, act, and make their own choice in ways that they believe the system can help to attain their goals (Friedman et al., 2013; Ligtvoet et al., 2015). **Data privacy and security** refers to a system that promote the protection of personal data. Additionally, this system allows people to determine which personal information can be collected, shared, used, and stored (Friedman et al., 2013).

2.3.3 Conclusion

This section addresses two primary topics regarding public values: (1) the definition of public values used in this research, and (2) the selection of public values that are considered essential in the energy sector. Deriving from the literature in public administration, the term "public values" refers to essential public convictions that are to be achieved by public policy. Accordingly, there are two primary characteristics of the public values: (1) public values are the values shared by the society as a whole, and (2) public values require the state's involvement for their protection and realisation. Based on this definition, public values can be clustered into two primary categories, i.e., substantive and procedural values. Table 2.1 summarises the essential energy sector's public values as well as their conceptualisation used in this research. A complete literature review on identified public values as well as their conceptualisation is presented in Appendix B.

Table 2.1: Substantive Values

Value	Conceptualisation	Reference(s)
Security of supply	Refers to promoting a low-risk of interruptions in electricity supply and, therefore, ensure the availability of electricity when needed even during peak times.	Demski et al. (2015); M. G. Edens and Lavrijssen (2019); Künneke et al. (2015); Ligtvoet et al. (2015)
Environmental sustainability	Refers to energy systems that allow contribution to climate goals through the reduction of GHG from the energy sector as well as promoting reduction of consumers energy use and allowing the integration of renewable energy into the electricity network in order to preserve environment for current and future generations.	Demski et al. (2015); Dignum et al. (2016); Milchram, de Kaa, et al. (2018); Milchram, Hillerbrand, et al. (2018)
Affordability	Affordability relates to the provision of energy that is as low as possible.	Bruijn and Dicke (2006); M. Edens (2017); Milchram, de Kaa, et al. (2018)

Table 2.2: Procedural Values

Value	Conceptualisation	Reference(s)
Procedural justice	Fairness in the process of decision-making by giving all relevant stakeholders same opportunity to participate in the decision-making process.	Demski et al. (2015); Dignum et al. (2016); Milchram, de Kaa, et al. (2018); Milchram, Hillerbrand, et al. (2018)
Distributive justice	Fair and equitable distribution and allocation of outcomes including benefits, costs, external or internal effects across individuals or groups.	Demski et al. (2015); Dignum et al. (2016); Friedman et al. (2013); Künneke et al. (2015); Ligtvoet et al. (2015); Milchram, Hillerbrand, et al. (2018)
Autonomy	Refers to a system which enables its users to obtain their own goals based on their own decisions and choices	Demski et al. (2015); Friedman et al. (2013); Ligtvoet et al. (2015)

Value	Conceptualisation	Reference(s)
Data privacy and security	Refers to a system that allows people to determine which personal information can be collected, shared, used, and stored.	Friedman et al. (2013)

2.4 Distribution of Tasks to Safeguard Public Values

Previous sections present the concept of the distribution of tasks, followed by public values used in this research. This section further explains the concept of distribution of tasks to safeguard public values by providing the definition of safeguarding public values used in this research. Following this definition, different safeguarding mechanisms based on literature are presented, followed by how these mechanisms are used in this research.

According to De Ridder (2010), there are three distinct characteristics of the term safeguarding of public values. First, safeguarding is an intervention. Second, safeguarding is an activity of the government or public bodies. Third, many public interventions may emerge to protect or realise public values. Therefore, the term safeguarding of public values implies any intervention or action taken by the state in order to realise or protect public values. In Corrà (2014), the states involvement in safeguarding public values may be necessary when the selected social system failed to realise or protect public values, known as "residual responsibility". To relate those theoretical contexts to this research, the government involvement is required to protect or realise public values when the distribution of tasks failed to realise or protect public values in order to fulfil their residual responsibility. The next question is how this research consider the distribution of tasks fails to realise or protect public values and how state fulfils this residual responsibility to safeguard public values.

In Corrà (2014), public values are safeguarded when public values are realised or protected. Accordingly, the distribution of tasks safeguards public values when actors are able to successfully deliver tasks associated with a certain public value. Nevertheless, actors may be responsible for multiple values that are incompatible[2] or different actors have different interpretations on what the value could be best served resulting in value conflicts (see, e.g., de Graaf, Huberts, & Smulders, 2016; Dignum et al., 2016). A value conflict may also emerge when: *"(1) a choice has to be made between at least two options for which at least two values are relevant as choice criteria, (2) at least two different values select at least two different options as best, and (3) the values do not trump[3] each other"* (van de Poel, 2011, p.177). In de Graaf and van der Wal (2010), the emergence of value conflicts may hamper the realisation of public values. Adhering to this line of reasoning, when distribution of tasks results in value conflicts, there is a possibility that public values are not realised or protected. As a result, government involvement may be required to ensure the realisation or protection of public values. The following section provides different types of government interventions in safeguarding public values, followed by which interventions are used in this research.

According to Charles et al. (2007), the fear that public values cannot be realised or protected in a framework of public-private ownership (in this case the decentralisation of energy systems) oftentimes results in a hierarchical safeguarding mechanism. This intervention implies that safeguarding public values is conducted by explicitly defining them and laying them down in "unambiguous and enforceable laws and regulations" (p. 7). Safeguarding public values via hierarchical mechanism offers a structural organisation for control, credibility, and the congregation of expertise that are well-suited to safeguard public values. Within this mechanism, it is assumed that the government is able to force the realisation of public values via regulations or laws. Therefore, this mechanism

[2]Incompatible means that the pursuit of a certain compromises the realisation of other values.
[3]Conflicting values are worth equally.

implies a "tight control" or "strict regulation" and assumes that each public value is clearly defined (Bruijn & Dicke, 2006; Charles et al., 2007). However, these assumptions are problematic, to say the least. Hierarchy leads to unintentional and unplanned prioritisation of values. Particularly when the specification of public values is difficult and, therefore, receives less attention. As a result, this condition leads to value trade-offs that are skewed towards certain groups of actors (limit on a possibility for effective trade-offs). Consequently, hierarchy induces strategic behaviour which may lead to inefficiency (Bruijn & Dicke, 2006; Charles et al., 2007; Corrà, 2014).

Departing from the hierarchy mechanism, (Bruijn & Dicke, 2006; Charles et al., 2007) note the use of market mechanism to safeguard public values. In a market mechanism, the government utilises market forces to protect public values instead of confronting and restricting them. To illustrate, during the energy transition process, sustainable energy producers emerge to offer green energy to consumers. In this case, the government provides subsidies or financial incentives to stimulate new market opportunities. Therefore, companies act in order to safeguard the sustainability value. However, market mechanism underestimates aspects of equity or equality as certain services are only accessible for a specific part of the society (see, e.g., Corrà, 2014; De Ridder, 2010). Additionally, it is worth noting that the concept of value trade-offs contains impracticability and even argued for and, therefore, entails public debate (Charles et al., 2007; Corrà, 2014; Steenhuisen, 2010).

Another practice of safeguarding public values is via network or community mechanism (Bruijn & Dicke, 2006; Charles et al., 2007; De Ridder, 2010). This mechanism emphasises that safeguarding public values should accommodate workable trade-offs among parties involved in the decision-making process. Additionally, it does not cease the existence of regulations or laws, rather public values are used to provide a universal and obtainable framework which guides the behaviour of any actors involved in the protection and realisation of public values, including the implementation and operation of certain policies. Although this mechanism helps to shape and achieve common goals based on trust and social interactions, it has a risk of excluding outsiders. Furthermore, workable trade-offs are debatable since each actor may have their own perceptions on each value. Consequently, this mechanism triggers debate because potential adverse effects on actors that experience value trade-offs (Charles et al., 2007; Corrà, 2014).

In essence, those three mechanisms have different ways of interventions, level of safeguarding, and tools of government. To exemplify, the market mechanism may promote efficiency; however, it undermines certain values such as equality or equity. On the other hand, the hierarchy mechanism ensures the realisation of public values yet it has detrimental effects on efficiency. Nevertheless, the complexity of decentralised energy systems indicates that the choice of safeguarding instruments cannot be based on general ideas of safeguarding public values. Rather it should depend on value systems and existing institutional practices as they constrain and shape the choices made regarding trade-offs and safeguarding mechanism (see, e.g., Charles et al., 2007; Goodin, 1998; March & Olsen, 2010). Accordingly, the choice of safeguarding mechanism relies on the context of the study in which safeguarding of public values is required.

To relate the above theoretical grounds to this research, the technical and social characteristics of decentralised energy systems determine safeguarding mechanism employed. According to Bruijn and Dicke (2006), a combination of hierarchical safeguarding, market mechanism, and network mechanism will lead to a more effective and efficient safeguarding of public values. This research will employ the same approach when value conflicts occur hampering the realisation or protection of public values.

To conclude, this section presents how this research operationalises distribution of tasks to safeguard public values. In this research, public values are safeguarded when actors are able to successfully deliver assigned task(s) associated with the realisation of public values. This definition implies that whenever value conflicts emerge, there is a possibility that public values are not realised or protected. In such a situation, government intervention is required to ensure the realisation of public values to fulfil their residual responsibility. There are three possible interventions that the government can take, hierarchical safeguarding, market mechanism, or network mechanism. Hierarchical implies safeguarding through regulations, market mechanism refers to safeguarding through market forces, and network mechanism which aims at providing workable trade-offs.

2.5 Conclusion

The chapter presents theoretical grounds that will be used to analyse the distribution of tasks to safeguard public values based on multiple critical concepts used in this research. This chapter aims at answering the following research sub-question: *How can the distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems be analysed?*

There are three key concepts proposed to analyse the distribution of tasks to safeguard public values—the distribution of tasks, public values, and safeguard public values. The **distribution of tasks** means tasks are distributed among actors according to efficiency, effectiveness, and equity (fairness). Following this definition, tasks are distributed based on the roles and resources of actors in decentralised energy systems. Additionally, this research focuses on six fundamental roles in the energy systems: **producer**, **balance responsible party**, **system operator**, **grid operator**, **supplier**, and **consumer**—and an additional role that emerges as a result of energy system change, i.e., **Energy Service Company (ESCo)**.

The second key concept is the public values. The term "**public values**" refers to essential public convictions that are to be achieved by public policy. Accordingly, there are two primary characteristics of the public values: (1) public values are the values shared by the society as a whole, and (2) public values require the state's involvement for their protection and realisation. There are seven public values that are identified as essential public values in the energy sector, **security of supply**, **environmental sustainability**, **affordability**, **procedural justice**, **distributive justice**, **autonomy**, and **data privacy and security**. These values can be categorised into two clusters, i.e., substantive and procedural values. The first three public values belong to the substantive values, whereas the remaining four are classified as procedural values.

The last essential concept is to safeguard public values. The term "safeguard public values" implies the protection or realisation of public values. By combining those theoretical grounds, the **distribution of tasks safeguard public values** when it can protect or realise public values. In this case, actors have successfully discharged the task(s) assigned to them. Nevertheless, actors may be responsible for multiple values or multiple actors are responsible for the protection of a single value. In this case, **value conflicts** may emerge, hindering the protection and realisation of public values. In such a situation, government intervention is required to ensure the realisation of public values to fulfil their **residual responsibility**—interventions required by the state to realise or protect public values. Throughout this report, the terms value, public value, and essential energy sector's public values will be used interchangeably.

It is important to mention that this analytical framework relies upon three notions: (1) actors' roles and resources can satisfy efficiency, effectiveness, and equity (fairness). This statement means that roles and resources can be used as grounds for tasks allocation, (2) the distribution of tasks safeguards public values when actors are able to successfully discharge their assigned task(s) in order to protect or realise public values. Accordingly, the distribution of tasks is unable to safeguard public values if actors face value conflicts, (3) value conflicts occur when: (a) the realisation of one value may hinder the realisation of other value or (b) multiple actors have different interpretations of what a specific public value could be best served. Figure 2.1 presents an overview of the analytical framework.

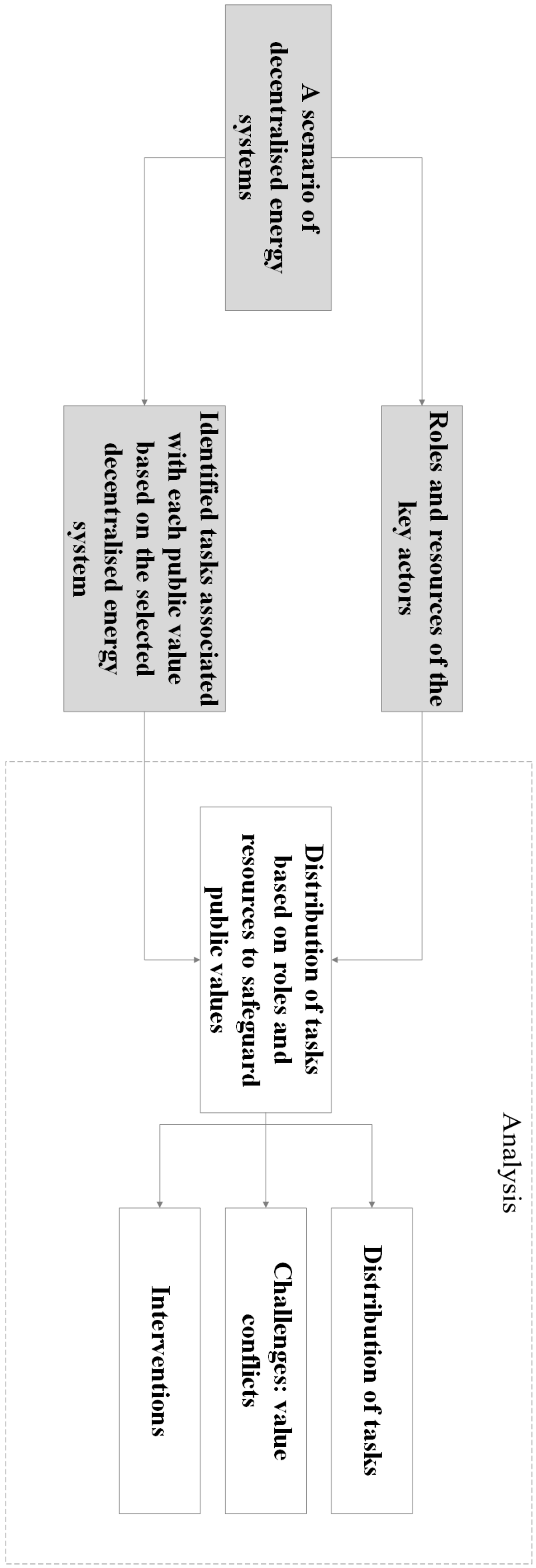

Figure 2.1: Analytical framework.

3. Research Methodology

Following the objective and research questions developed in Chapter 1, this chapter presents the methodology used to develop the scenario for decentralised energy systems and the identification of roles, resources, and tasks. Section 3.1 explains the scenario development used to answer sub-question 2. Next, the methods for identification of roles, resources, and tasks are discussed in Section 3.2.

3.1 Qualitative Scenario Planning

To understand the application of the distribution of tasks to safeguard public values in decentralised energy systems, it is important to define which scenario is used since different scenarios may have different results. This section focuses on the idea behind the use of scenario for this research, followed by the building blocks used to develop the chosen scenario.

3.1.1 Why Scenario?

In Chapter 1, an introduction of the problem at hand is presented. In sum, there is an ongoing movement towards decentralised energy systems, posing challenges to the current electricity system because new tasks emerge, putting public values at stake. Furthermore, this transformation carries many uncertainties concerning how decentralised energy systems look like in the future. Mainly because this shift occurs in a large interdependencies environment where many actors are involved in delivering energy services, therefore, when there are many uncertainties about a future system environment, scenario planning is used to explore possible future (see, e.g., P. Schwartz, 1991; Van Notten, Rotmans, Van Asselt, & Rothman, 2003).

A scenario is "a narrative description of a consistent set of factors which define in a probabilistic sense alternative set of future business conditions" (Huss, 1988, p.378). Therefore, a scenario focuses on identifying possible futures. Meanwhile, a scenario planning is "a paradigmatic way of strategic thinking that acknowledges uncertainty with all the consequences this entails" (van der Heijden, 2011, p.19). Within this research, the use of scenario planning is to *explore* a possible future of decentralised energy systems based on current trends in the energy sector. It is used to raise awareness, stimulating creative thinking, and gaining insight into the application of the distribution of tasks to safeguard public values (Van Notten et al., 2003). Since the subject of the study is to explore a possible scenario of decentralised energy systems, an intuitive approach to scenario planning is adopted. This selection implies that the scenario planning leans on the qualitative knowledge and insights from which a scenario is developed (van Notten, 2006).

3.1.2 Research Design

This study follows a scenario planning proposed by Van Notten et al. (2003) which consists of three overarching steps: (1) project goal, (2) process design, and (3) scenario content. Before further discussion on this approach, it is essential to provide some clarifications. First, a scenario is not a forecast; it is a possible future. Second, this research only focuses on a single scenario synthesising from current trends and developments in the Dutch energy sector with a limited scope that is discussed in the subsequent section.

As stated in the previous section, an intuitive approach to scenario planning relies on the qualitative knowledge from which a scenario is developed. Accordingly, an extensive literature review of current decentralised energy projects is conducted (see Appendix C) to enrich an understanding of current trends in the Dutch energy sector. The information gathered from this study serves as a basic understanding of the trends in the Dutch energy sector, which initiates relevant trends for the scenario planning process and are used to formulate the final scenario.

Following the identification of the trends in the Dutch energy sector, the next step is to develop overarching themes to reduce information complexity (Lindgren & Bandhold, 2003). According to these findings, identified trends are used as the backbone for scenario development. Creative thinking techniques are used to fill in the details of the selected scenario and assist in discussing the identified trends and their characteristics. Any assumption made for the scenario development is documented in Appendix A. Figure 3.1 provides a graphical representation of these three stages of research design compared to the scenario planning steps proposed by Van Notten et al. (2003).

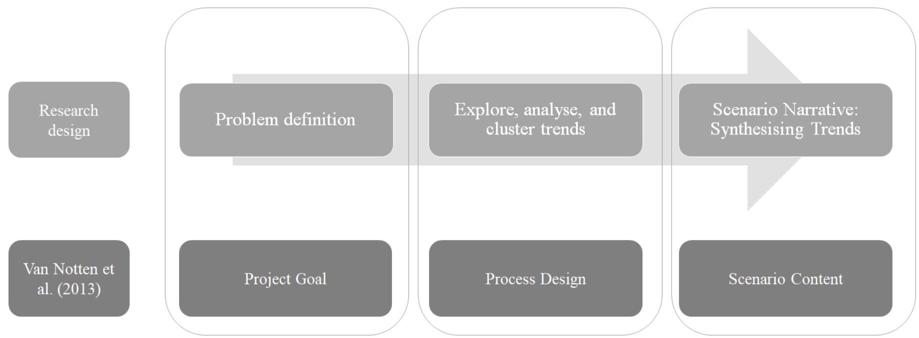

Figure 3.1: Method for scenario planning.

3.1.3 Data Collection

This section provides the strategy used for data collection for the three stages described in the previous section. Before further discussion, the data needed for stage 1 is equal to the information provided in Chapter 1 and Chapter 2. Therefore, the following section elaborates on the data collection strategies for the remaining research stages chosen for this research.

Literature Review: Identification of Trends

The literature review aims at exploring various trends and developments in the Dutch energy systems. To achieve such an objective, the focuses of the literature review are twofold. First, to identify societal trends in the power systems, for example, societal drivers for energy system change.

Second, to identify technological trends towards decentralised energy systems. Accordingly, there are two primary resources for the literature review, scientific literature and grey literature. In this research, the literature review starts with grey literature such as news, government documents, and company reports to map different trends in the Dutch energy sector. This choice is made because the study focuses on the Dutch energy sector, which may have specific trends compared to other countries. Additionally, the identification of trends in the current Dutch electricity sector is used as the basis for the exploration of possible futures. The starting point for grey literature identification is based on the current projects in decentralised energy systems, as presented in Appendix C.

Subsequently, the literature review on scientific articles is conducted to add additional information found in grey literature. For scientific literature, the search process is conducted by utilising specific keywords on online databases such as Scopus, Web of Science, and Google Scholar. These keywords are selected to focus on contents related to relevant trends and attributes in the power systems. Furthermore, these keywords are often used in combination with other keywords to allow more focus on desirable outcomes. If such results do not fulfil the demand of identifying various trends, a snowballing strategy is utilised to locate other articles used by authors as references to shape their works. Table 3.1 presents the keywords used for the research. The combination of grey literature and scientific articles is used to avoid publication bias. For instance, grey literature is utilised to identify trends or drives from commercial enterprises' perspectives. Meanwhile, the scientific literature is used to identify the limitations of recent technological innovations in the energy sector.

Table 3.1: Keywords Used for Literature Review

Subject	Focus keywords for literature review
Trends in the electricity systems	decentralised AND energy AND systems
	community AND energy AND systems OR local AND energy AND systems
	distributed AND energy AND resources AND energy AND systems AND integration
	decentralised energy systems OR decentralized energy systems OR distributed energy systems

3.1.4 Trend analysis

This section describes the results of the activities described in Figure 3.1. The order of the following section reflects the steps taken to identify trends and clusters.

Trends and Clusters

Based on the above data collection, a total of 31 documents (both grey and scientific literature) are selected, which are listed in Appendix C. Each document is scanned, and trends that have: (1) the degree of impact, and (2) the uncertainty surrounding the trends (Enserink et al., 2010) are selected. The degree of impact implies that trends need to have an impact because only then trends are likely to lead changes in the future. Meanwhile, uncertainty leads to different types of future (P. Schwartz, 1991). By identifying trends based on these two criteria, there are six individual trends used as building blocks for the scenario development, as shown in Table 3.2.

Following the identification of individual trends, trends are clustered to reduce information complexity (Lindgren & Bandhold, 2003). They are clustered based on the theme of each individual trends. To provide clarity, two examples are given:

Example of Trends and Clusters

1. **Identified trend 1**: New service providers emerge offering different types of services such as energy trading, and flexibility (Stedin & Energy21, 2018).
2. **Identified trend 2**: New service providers offer new procurement of electricity via online platform (Powerpeers, 2019).

These two identified trends are clustered under the theme of "New emerging actors and services may emerge to leverage local assets.". Once clustered, the STEEP framework is used to analyse the identified clustered trends based on their relevance and categorise them according to Social, Technological, Economic, Environmental, and Political (STEEP). The use of the STEEP framework is necessary to keep the clustered trends structured in order to increase manageability and critically review the clustered trends found in the previous step. Additionally, it is also used to merge some identified clusters that are similar in order to improve manageability. Furthermore, it allows permeating through different types of trends in the electricity systems, instead of only focusing on one specific sector. Consequently, these categories are the lens through which the future of energy systems could be approached. For this study, the environmental aspect is often embedded in the social and technical aspects of the development of decentralised energy systems. Therefore, the environmental aspect is omitted. Table 3.2 presents the results from these steps, which serves as an outline for the scenario's description. Additionally, each cluster has one or more examples to provide clarity on the clustering of trends.

Table 3.2: Identified Trends of Decentralised Energy Systems

Aspect(s)	Cluster(s)	Trends(s)	References
Social Drivers	Increase social awareness	Change in societal views on the energy system: Societal changes towards decentralised energy system that are driven by self-sufficiency and a more control over supply.	Koirala et al. (2016); Moraga and Mulder (2018); Powerpeers (2019); Sonnen Group (2019); Stedin and Energy21 (2018); Universal Smart Energy Framework (2015); van der Schoor and Scholtens (2015)
Technology	Technological infrastructure and innovations	The integration of "internet" into the energy sector opens up opportunities for a wide range of energy products.	Bayram, Shakir, Abdallah, and Qaraqe (2014); Jogunola et al. (2017); Kloppenburg and Boekelo (2019); Milchram, de Kaa, et al. (2018); Morstyn et al. (2018); Shaukat et al. (2018); Sousa et al. (2019); Zhang, Wu, Zhou, Cheng, and Long (2018)
		Different scale of the system (e.g. community, regional, or cross-border) affects the location of energy supply which leads to different operating mechanism.	Koirala et al. (2016); Long, Wu, Zhang, Cheng, and Al-Wakeel (2017); Parag and Sovacool (2016); Saboori, Mohammadi, and Taghe (2011); Stedin and Energy21 (2018)
		Different types of networks that may emerge based on the aggregation of the consumers and prosumers as well as the nature of distributed energy production and consumption.	Bayram et al. (2014); Jogunola et al. (2017); Koirala et al. (2016); Long et al. (2017); Parag and Sovacool (2016); Saboori et al. (2011); Sorin, Bobo, and Pinson (2019); Sousa et al. (2019)
Economy	New emerging actors and services may emerge to leverage local assets.	New service providers in the energy sector offering different types of services such as energy trading, and flexibility.	Gkatzikis, Koutsopoulos, and Salonidis (2013); Parag and Sovacool (2016); Saboori et al. (2011); Stedin and Energy21 (2018)

Aspect(s)	Cluster(s)	Trends(s)	References
Policy	Regulatory	Types of regulatory required to enable decentralised energy system.	Mengelkamp et al. (2018); B. Moreno, López, and García-Álvarez (2012); Stedin and Energy21 (2018)

For this report, it is important to mention that only the scenario's outcome is presented in Chapter 4. The result of the above stages can be found in Appendix C.3. Additionally, the description of the selected scenario is divided into three overarching sections in order to provide clarity. The first section is the enablers of the scenario, which consists of social, technical, and regulatory aspects identified in Table 3.2. The second section focuses on the economic values offered by the selected scenario (value propositions). Lastly, new actors that emerge to support the selected scenario are discussed, and an illustration of actors' arrangement is presented.

Limitations

The selected method to build the scenario has some limitations that need to be acknowledged. One prominent issue is the subjectivity of the researcher. Although an extensive literature review is conducted to limit bias, the built scenario is still based on the level of knowledge and experience of the researcher. Therefore, assumptions used and choices made are important to be included in this research as those factors affect the outcomes of the scenario (Rounsevell & Metzger, 2010). Assumptions and choices of the scenario are provided in Appendix A. Furthermore, given the qualitative nature of this research, the outcome of the scenario is difficult to validate, because limitation of empirical data in which the scenario can be tested since the scenario describes the uncertain future. Consequently, the credibility of the scenario can be questioned (Rounsevell & Metzger, 2010). Therefore, it is important to understand that the scenario is not built to provide an exact image of the future; rather, it should be seen as a possible future (Schoemaker, 2004).

Nevertheless, to increase the validity (check the accuracy of the findings) of this research, a few procedures are added. According to Amer, Daim, and Jetter (2013), a scenario should be plausible, consistent, creative, and relevant to the present trends. Therefore, a preliminary literature review on the current developments of the Dutch energy projects is conducted. Based on this information, different trends can be identified in order to provide the basis of scenario development. Based on this identification, the scenario is selected based on three primary drivers: (1) more control oversupply, (2) sustainability, and (3) self-sufficiency. These drivers are selected because the current development in the Netherlands are based on these three drivers. For example, projects like Gridflex Heeten (GridFlex, 2018), Vandebron (Zhang, Wu, Long, & Cheng, 2017), and Powerpeers (Powerpeers, 2019) (see Appendix C. Furthermore, in order to increase the validity of the identified trends, scientific articles and grey documents are used to provide triangulation of the data. The results of this study and the list of the selected documents are provided in Appendix C.

3.2 Identification of Roles, Resources, and Tasks

The following section provides the methodology for roles, resources, and tasks' identification based on the selected scenario, as mentioned in the previous section. Additionally, the identification of roles, resources, and tasks utilise the list of literature used to build the scenario in the previous section in order to increase the internal validity and reliability of the research (Appendix C).

In this research, a role describes interactions between actors in the system concerning a given business transaction (ENTSO-E, 2015). In other words, actors engage in activities by performing role(s) like system operator, producer, or supplier. Following the identification of actors in the previous section, each actor assumes role(s) based on their relations with other actors in the network. As mentioned in Chapter 2, this research only focuses on a limited number of roles in order to limit the scope of the study (definition of each role used in this study can be found in Appendix D.2).

Meanwhile, the identification of resources is based on their role(s) in the systems. Since some actors are emerging actors, their role(s) and resource(s) are often assumed based on their activities in the selected scenario. For example, the resources of prosumers are assumed to be solar panels and energy storage due to their involvement in providing energy services through online platforms. Assumption made for role(s) and resource(s) are compiled in Appendix A.

As described in Chapter 2, a task is identified based on the conceptualisation of public values that are reflected in the scenario. In order to provide clarity, the identification of tasks is based on the selected scenario provided in the previous section. Therefore, the scenario's description is presented in a rather detail manner in order to allow identification of tasks. Two examples are given:

Example of Tasks Identification

1. **Conceptualisation of autonomy**: Refers to a system which enables its users to obtain their own goals based on their own decisions and choices (Demski et al., 2015; Friedman et al., 2013; Ligtvoet et al., 2015).
2. **Tasks Identified from the selected scenario**: A distinct advantage of energy trading via an online platform is attributed to its ability to *facilitate direct trades between consumers and prosumers according to the individual's preferences such as minimise costs, maximise profits, or energy mix* (Morstyn et al., 2018).

Based on the conceptualisation of autonomy (see Chapter 2), the task of facilitating direct trades according to the individual's preferences is associated with the realisation of the autonomy value. Since this task is not yet recognised in the current electricity system, this task is considered as a new emerging task and, therefore, is added to the list of tasks required to realise the autonomy value. To limit the feasibility of the study, a limited number of emerging tasks are used for this study. To ensure that the identified emerging tasks are relevant, an additional literature review is conducted on each identified task used in this study. The tasks that are identified and used in this study are presented in Section 4.2.2.

Limitations

The identification of tasks is based on the selected literature for building the scenario. Therefore, some tasks may not be identified due to the scope of the literature used for this study. Additionally, tasks that are associated with each public value is based on the conceptualisation of public value presented in Chapter 2. Consequently, it is limited to the conceptualisation of public values. This choice also implies that the conceptualisation of each public value plays an important role in identifying task(s) that are related to the realisation of public values. However, public values are generally used in a wide variety of study, and their conceptualisation is rather abstract. As a consequence, challenges arise due to the level of abstraction. As a result, this research limits the number of identified tasks according to the co-occurrences in the literature.

3.3 Conclusion

This chapter specified research methodology of this research project. Qualitative scenario planning is selected due to the nature of this study that involves many uncertainties regarding trends and developments in the Dutch energy sector. This method is used to identify a plausible future scenario that is used as a means to study the distribution of tasks to safeguard public values. Additionally, the intuitive approach to scenario planning is selected because the exploratory nature of this study. Three overarching steps proposed by Van Notten et al. (2003) is used to develop a scenario of decentralised energy systems. Additionally, the STEEP framework is used to categorise clustered trends in order to provide the basis for scenario description. Once the scenario is built, roles, resources, and tasks are identified to provide the basis for the subsequent analysis. A role is identified based on the interactions between actors with regard to a given business transaction. Resources are practical means that actors have to realise their role(s). Lastly, tasks are identified based on the conceptualisation of public values reflected in the chosen scenario. It is important to mention that due to the nature of the study, empirical data is limited and, therefore, additional assumptions are made in order to fill in the gaps in the presented results. Any assumptions made for this study are compiled in Appendix C.

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Part Three: Result

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4. A Scenario of Decentralised Energy Systems

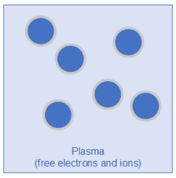
A paradigm shift in the electricity system produces new opportunities and challenges for not only incumbents but also other new emerging actors providing new services to support such a system. The trends towards new electricity system driven by electrification of various industries, decentralisation of energy production, and digitalisation of energy information, among others, lead to many uncertainties of the future energy system. Such trends could result in a variety of potential futures depending on how each actor in the electricity system approaches challenges in the energy sector via the use of technological innovations. By exploring those facets, a scenario of decentralised energy systems is generated—Plasma.[a] Therefore, this chapter aims at providing a possible scenario of decentralised energy systems based on current trends and developments in the Netherlands. Therefore, this chapter provides an answer to the second sub-question:

What is a scenario of decentralised energy systems based on current trends and developments?

In **Section 4.1**, an overview of the Plasma scenario is presented. This section describes the drivers, enablers, and value propositions associated with the Plasma Scenario. **Section 4.2** discusses different types of actors that involve in the Plasma scenario, followed by a diagram that represents interactions between actors in this scenario. This section also explores the roles and resources for each actor as well as identifies tasks associated with essential energy sector's public values as identified in Chapter 2 that are going to be used for the subsequent analysis. This section concludes with a summary of the scenario **(Section 4.3**).

[a]The Scenario names reflect the states of matter to give a sense of different bonds for each scenario.

4.1 The Plasma Scenario: A Possible Future



Plasma is a digitalised energy landscape shaped by a highly complex and fast-paced technological innovations in the energy sector. Magnified by high penetration of renewable technologies, this concept allows a wider geographical area of energy utilisation.

Growing awareness towards reducing CO_2 emission and dependence on fossil fuels have led to the rapid growth of renewable energy generation. At the same time, a social change towards renewable energy generation has also caused the need to gain more control over energy supply. The Plasma scenario explores future decentralised energy systems where the integration of renewable energy generation is driven by societal attitudes towards sustainability, self-sufficiency, and more control over energy supply. Combined with the declining costs of renewable technologies as well as grid advancements, solar panels, energy storage, and load management become prevalent in society. As a result, new actors emerge to provide new services in order to accommodate consumers' demands while promoting efficient allocation of resources by capitalising on underutilised assets. These new entrants are accelerating the developments of technological innovations to support decentralised energy systems by facilitating the growth of "virtual" energy communities. As a result, new services emerge to substitute the conventional way of energy procurement, allowing consumers to select a mix of predominantly green energy to satisfy their electricity needs. This section elaborates upon the era of "virtually connected" energy communities in which individuals are able to directly communicate with each other to maximise the use of their excess assets to achieve more control oversupply, sustainability, and self-sufficiency.

4.1.1 Enablers of the Plasma scenario

The Plasma scenario is driven by four core enablers—declining costs of renewable technologies, technological innovations to facilitate energy trading, behaviour changes of energy consumption and production, and regulatory framework to facilitate energy services. The declining costs of renewable technologies are an essential factor in the Plasma scenario since it empowers citizens to gain more access to energy production and distribution that were unattainable in the past (Koirala et al., 2016; Stedin & Energy21, 2018). These renewable technologies are categorised into three primary categories, energy production, storage, and information transfer (Ruotsalainen, Karjalainen, Child, & Heinonen, 2017). In the energy production category, price value is considered as a pivotal factor for the investment decisions with respect to energy production, which are related to the cost of purchasing a solar system, payback period, and reliability of the system. In the energy storage, the ownership of home-based battery is considered as a critical factor to enable the Plasma scenario. This is because excess energy can be stored to allow higher flexibility on the grid instead of selling it back to the grid. Additionally, excess flexibility can also be traded to offer others who require more flexibility in their network, enabling additional incentives to the ownership of energy storage (Klaassen, 2016; Ponds, Arefi, Sayigh, & Ledwich, 2018).

In the light of declining costs of renewable technologies, the transition towards Plasma scenario is closely related to the technological innovations in the energy sector which are utilised for the provision of energy services, i.e., digitalisation of energy-related information, and technical infrastructure (Bayram et al., 2014; Sousa et al., 2019). The integration of Internet of Things (IoT) devices in the energy sector plays a vital role in the development of the Plasma scenario because foregoing developments in the provision of energy services have made metering data more critical than ever (Bayram et al., 2014; Jogunola et al., 2017; Sousa et al., 2019). The digitalisation of data such as energy production and consumption enables data transfer between devices and actors in the system, which is essential because the operation of the Plasma scenario relies on the reliability of energy-related information for financial settlements and balancing process. In the technical infrastructure, the upgrade of power grid resulting in the so-called smart grid system because it accounts for volatility of energy supply and a rising number of decentralised energy generation through the digitalisation of energy-related information (Milchram, de Kaa, et al., 2018; Shaukat et al., 2018).

In line with the emphasis on declining costs and technological innovations, behaviour changes in energy consumption and production are pivotal points to enable trades of energy products between members within the network. This aspect is essential to improve energy utilisation in the community as well as enable the emergence of "virtual" energy markets. For instance, a behavioural change to offer excess energy supply is key to the implementation of energy efficiency. Additionally, policy measures to eliminate the green tax for small-scale producers and net-metering schemes are introduced, adding economic values to provide balancing services (Klaassen & Van Der Laan, 2019).

4.1.2 Value Propositions

The Plasma scenario adopts a decentralised approach that offers an autonomous decision on energy trading and balancing services, allowing its participants to capitalise on their distributed assets. A distinct advantage of energy trading is attributed to its ability to facilitate direct trades between consumers and prosumers according to the individual's preferences such as minimise costs, maximise profits, or energy mix (Morstyn et al., 2018; Zhang, 2017). Consequently, the Plasma scenario allows its participants to decide their involvement in any energy-related activity based on their predefined values. Apart from promoting freedom of choice, the concept of energy sharing between peers is introduced to increase the allocation of resources which in turn promotes sustainable and affordable energy procurement (see, e.g., Kloppenburg & Boekelo, 2019). Nonetheless, bidirectional energy flows on the grid pose challenges to the incumbents resulting in possible interventions to ensure the reliability of the distribution network. The Plasma scenario addresses this challenge by ensuring a local balance between energy supply and demand within the network during electricity delivery. However, a single peer may frequently be unable to meet the required demand to provide a balancing requirement due to their limited volume. This is where the added value of this scenario comes from. This scenario unlocks added-values of consumers and prosumers' flexible assets through an aggregation, enabling self-balancing compared to a single unit asset. Therefore, the combination of balancing services and energy trading provides economic benefits to members in the network (Morstyn et al., 2018).

Additionally, the Plasma scenario endorses a peer-to-peer (P2P) network structure[1] which allows each peer[2] within the network to directly communicate their energy needs. Since this structure represents a bottom-up approach, its network is more flexible and autonomous. In other words, the network can grow or shrink in size depending on the number of participants in the network (Parag & Sovacool, 2016). Combined with technological innovations such as digitalisation of energy-related data and online trading platform, the distribution of energy in the Plasma scenario is not restricted by geographical location (see, e.g., Powerpeers, 2019; Sonnen Group, 2019). This notion also implies that the Plasma scenario does not have an independent grid infrastructure to distribute energy; rather, it relies on the existing infrastructure for the execution of electricity delivery. As a consequence, the electricity is traded "virtually", which implies that the electricity

[1] A P2P network represents an information network and is not a physical electricity connection.

[2] A peer in this network refers to one or more energy costumers including generators, consumers, and prosumers (Zhang et al., 2018).

consumed is not necessary from a certain prosumer rather a flow of information that certifies the origin to be sourced from a certain prosumer.

To conclude, the above information provides an overview of services offered by the Plasma scenario. Conceptually, this model has its own incentives to its participants and other market participants in the electricity system: (1) it allows the distribution of excess electricity, which promotes energy efficiency, and (2) it enables access to flexibility for other market participants. These services allows participants in the Plasma scenario to capitalise their local assets in return for economic benefits. The word "virtual" for this scenario; however, it is important to emphasise on, since the physical flow of electricity is executed through the existing infrastructure.

4.2 Actors and New Emerging Tasks in the Plasma Scenario

Deriving from the aforementioned information, it is clear that a shift towards the Plasma scenario involves a changing network structure, and new actors and services are expected to emerge in order to enable the integration of distributed energy generation into the existing power system. At an individual level, the transition towards distributed energy generation has resulted in the social transformation of the end-users from energy consumers to prosumers. At a community level, emerging actors such as independent service providers (ISPs) materialise to facilitate trades between members within the networks as well as facilitating the provision of balancing services. Additionally, the emergence of ISPs replaces the need for energy supplier since prosumers have a contractual agreement with ISPs for energy supply. Nevertheless, it is worth mentioning that the emergence of new actors and services does not imply that incumbent actors cease to exist. Rather they operate in parallel with this new system or assume a role to support the operation of the Plasma scenario. For instance, the involvement of Balance Responsibility Parties (BRPs) is still required in order to assume the balancing responsibility of the members in the system. Their involvement is mandatory since it is expected that the balancing responsibility is still obligatory for each party connected to the grid. Figure 4.1 illustrates key actors' relations in the Plasma scenario.

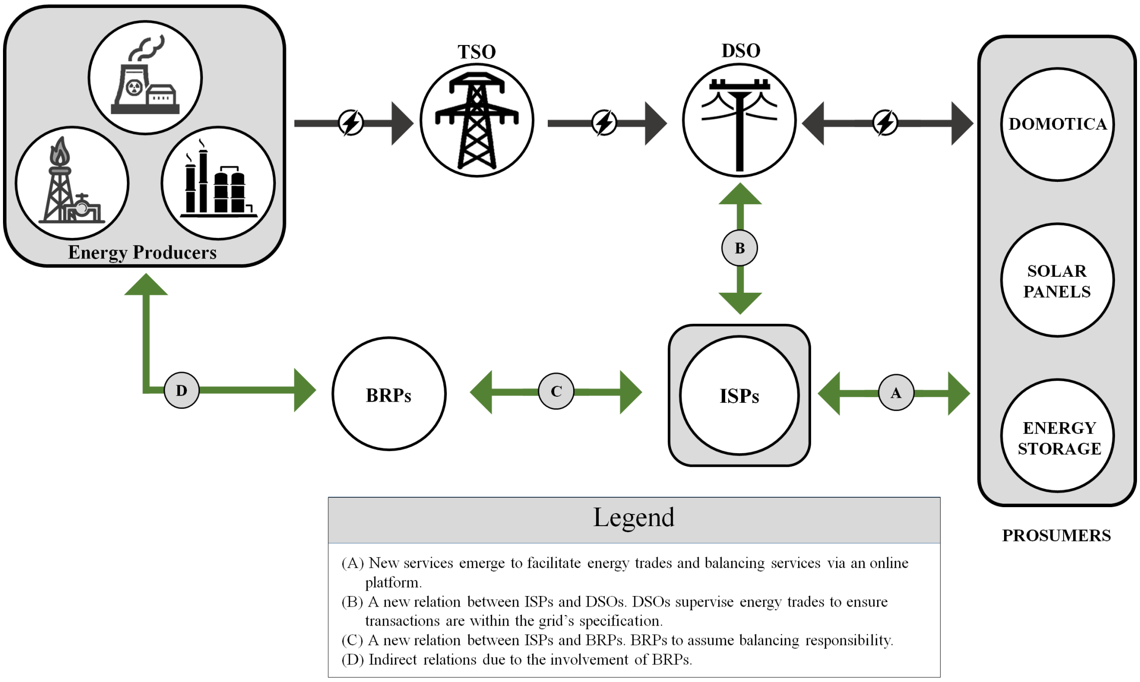


Figure 4.1: Illustration of key actors' relations in the Plasma scenario.

4.2.1 The Roles and Resources of the Key Actors

According to the aforementioned section, a number of key actors are identified. In the technical layer, the conventional actors traditionally existing are still present, i.e., **energy producers**, **transmission system operator**, **distribution system operators**, **balance responsible party**, and **prosumer**[3]. New actors, **ISPs**, emerges to support and provide additional services to the consumers. The following information provides an overview of actors roles and resources according to the identified roles in Chapter 2. Assumptions that are made for the following section are compiled in Appendix A.

Prosumers

Prosumers appear as a result of the transition towards decentralised energy generation. They produce electricity (which is distributed through the grid) and sell it via the energy platform. Therefore, prosumers are connected to the grid network in order to trade their electricity. As a consequence, it is assumed that prosumers hold a role of energy producers. In relation to the resources, prosumers are assumed to have a wide variety of resources. First, the ownership of decentralised energy resources (solar PV, energy storage, and home automation system) and technological infrastructure provided by independent service providers (in-house smart monitoring device) and the grid operators (smart meter). The ownership of such resources allows prosumers to trade electricity as well as receive remuneration due to offered services. Second, access to the trading platform, which implies the need for contractual agreements between prosumers and independent service providers (ISPs). Third, as the scenario emphasises on the ownership of distributed energy resources as well as technological infrastructure, sufficient access to finance is considered one of the resources of prosumers.

Transmission System Operator (TSO)

In this scenario, TSO still assumes the role of the system operator at the national transmission grid. It indicates that TSO is required to maintain a stable power system operation (including network balancing), managing import capacity, and balancing the electricity supply with demand (de Vries et al., 2017). However, due to the focus of the study, this research will only focus on the role of DSOs are the system operator at the distribution level and, therefore, TSO's involvement is not included in the study.

Distribution System Operator (DSOs)

DSO assumes a role as the system operator at the distribution level. Within this role, DSOs are expected to facilitate the integration of prosumers, network operations, and planning and asset management. Accordingly, DSOs have a diverse range of resources. The tangible resources of DSOs are the physical grid infrastructure as well as financial resources. These assets are related to their function in the electricity system, particularly regarding their activities in maintaining the distribution networks to accommodate the integration of prosumers and their assets. These activities also indicate that DSOs have resources in the form of energy-related information from different market participants such as conventional energy suppliers or ISPs based on corresponding regulatory frameworks, which is used for network operations. Therefore, DSOs have both technical knowledge and human resources for supporting all those activities.

Independent Service Providers (ISPs)

ISPs assume multiple roles due to their services to their customers: Energy Service Company (ESCo), energy supplier, and local data manager. The role of ISPs, such as ESCo, relates to the provision of energy trading and self-balancing services offered to their participants. Meanwhile, the role of energy suppliers is enabled when customers enter contractual agreements with ISPs with regard to services provided by ISPs. In the context of the research, the role of an energy supplier

[3] In the selected scenario it is assumed that consumers are prosumers in the future.

provides a legal requirement for any transaction occurring within the network (that utilises the existing power system) and settles any fees and costs associated with each transaction. By entering contractual agreements with the ISPs, the ISPs provide legal requirements for each member in the network such as a license to trade energy products.

In both cases, ISPs collect data from smart devices offered to their members to generate precise information for energy production and consumption as well as for balancing purpose. By this line of reasoning, ISPs assume the role of data manager for their own network. This role is separated from the role of DSOs as data facilitator for the wholesale market. Accordingly, ISPs have multiple resources such as access to customers information, technical knowledge in network management and energy efficiency, and access to technological infrastructure offered to their customers for efficient allocation of resources.

Balance Responsible Parties (BRPs)

In the electricity markets, consumers and energy suppliers have contractual agreements that specify how much electricity they are buying and selling. However, the actual amount of electricity consumed or traded might differ from the contracted amount. As a result, programme responsibility is required for each member of the network. The programme responsibility entails that each entity connected to the physical grid and actively involved in the electricity markets is required to balance their own energy supply and demand in order to avoid any disruption. In the proposed scenario, ISPs are expected to organise contracts for local balancing services provider based on an agreed fee which will be distributed among their members in the network. The primary resource of BRPs is a financial capacity to contribute to the balance of the electricity system by way of balancing its own position due to the ownership of a large flexible portfolio.

Centralised Energy Producers

Centralised Energy Producers is generally considered as conventional actors. Their involvement is because BRPs assumes balancing responsibility for ISPs. With regard to the resources, the energy generators own the traditional resources as energy generators such as physical resources (natural resources and power plants) and financial resources.

Autoriteit Consument en Markt (ACM)

ACM supervises the compliance of the Electricity and Gas Law. The role of ACM is to protect energy customers interests and safeguard competition in the market. ACM is enforcement, intending to prevent and resolve market and energy customers problems. Furthermore, ACM also supervises regulations of third-party access and tariffs related to the Dutch electricity market. ACM has powers to impose a sanction upon infringements of the Acts.

Ministry of Economic Affairs

Ministry of Economic Affairs supervises the compliance of the Electricity and Gas Law with regard to security of supply, network access conditions, and tariff structures. The Ministry of Economic Affairs plays an important role in balancing interests to accommodate flexibility services in the market. It has capacities to amend laws (e.g., for tariff distribution, data privacy, or competition in the market) and access to perform capital injections by offering several funding options (e.g., incentives or subsidies) (SGTF-EG3, 2015).

4.2.2 New Emerging Tasks in the Plasma Scenario

New emerging tasks are identified from the description of the proposed scenario. The following section provides an overview of new emerging tasks that might emerge with the adoption of the selected scenario.

Security of supply

According to the proposed scenario, the notion of security of supply is associated with the ability of decentralised energy systems to supply energy based on time, quantity, and quality demanded by the user (Zhang, 2017). Stedin and Energy21 (2018) address issues concerning the reliability of renewable technologies when renewable energy sources are not available. Particularly because the weather condition in the Netherlands causes fluctuations in energy supply and demand. Therefore, a new task to Manage fluctuations caused by the integration of decentralised energy generation and energy trades emerge (see, e.g., Lammers & Diestelmeier, 2017). Consequently, in the context of this research, security supply relates to multiple subjects. First, the reliability of the built systems in order to supply energy based on time, quantity, and quality. Second, the requirements to manage fluctuations caused by the adoption of decentralised energy systems.

Affordability

According to the scenario description, the selected scenario offers additional economic value by incentivising underutilised assets. For instance, the notion of energy sharing between peers is introduced to increase the allocation of resources, which in turn promotes sustainable and affordable energy procurement (see, e.g., Kloppenburg & Boekelo, 2019). Additionally, the balancing services offered by the proposed scenario is expected to contribute to reducing the electricity bill paid by the members in the network (Klaassen & Van Der Laan, 2019; Morstyn et al., 2018). Affordability relates to the provision of electricity that is as low as possible.

Environmental sustainability

Environmental value is related to the availability of raw materials for renewable technologies. Grandell et al. (2016) identify possible scarcity of material resources caused by the dependence on critical metals to produce low-carbon technologies such as solar PV, energy storage, or windmills. Such bottlenecks may lead to higher costs for renewable technologies, particularly solar PV modules which will hinder the penetration of such technology. It is, therefore, recommended to concentrate on recycling and possible material substitutions which are not dependent on critical materials. Likewise, similar problems may arise with the use of lithium-ion batteries at a large scale without recycling efforts. As of now, there is no readily scalable alternative to lithium supplies imposing risks to technological diversity (Kushnir & Sandén, 2012). Apart from the material, the use of technological innovations in the energy sector is expected to reduce dependence on fossil fuels by promoting efficient allocation of resources (Kloppenburg & Boekelo, 2019). As a result, the environmental sustainability relates to the technological developments in renewable technologies which consider the impacts of such developments on the environment as well as the coordination of renewable generation to reduce dependence on fossil fuels.

Distributive justice

In distributive justice, there are three main points. The first one relates to an equitable distribution of costs, including the negative effects, based on individual contribution (Stedin & Energy21, 2018). This task is important because the integration of decentralised energy systems not only affects actors who are involved in the systems but also others who are not involved in the systems (Jägemann, Hagspiel, & Lindenberger, 2013; McKenna, 2018). A common subject that is related to this task is the heterogeneity of societies. In a situation where people have access to a diverse range of renewable technologies, they could reduce their electricity bills. Meanwhile, for others who have limited access to renewable technologies, they might be affected negatively due to the costs associated with grid operations (e.g., reserves and grid reinforcement)) (see, e.g., McKenna, 2018; Stedin & Energy21, 2018). The second one relates to equal access to renewable technologies (see, e.g., Engerati, 2018). The third one relates to equal access to distribution networks. This task emerges because the growth of decentralised energy generation connected to the grid is faster than the grid enforcement, resulting in scarcity in grid capacity (ACM, 2019a).

Procedural justice

There are two emerging tasks as a result of the selected scenario. First, ensuring transparency in the provision of energy services (ACM, 2019b; Morstyn et al., 2018; Zhang et al., 2017). This task relates to the access to grid information that allows all commercial actors to compete on an equal footing. The second task relates to equal opportunity for all actors in decision-making process. It relates to the provision of information in order to participate in energy services provided by the scenario (Kloppenburg & Boekelo, 2019).

Autonomy

As described in the selected scenario, its emergence of the selected scenario has been attributed to the ability to choose their own energy suppliers as well as a more control over energy supply (Morstyn et al., 2018; Stedin & Energy21, 2018; Zhang, 2017). However, it might also trigger a monopoly when a single entity is assumed too much control and power (Kloppenburg & Boekelo, 2019). As a consequence, the notion of autonomy relates to a system developed in a way it does not threaten self-governance, freedom of choice, and compromise the ability to control personal aspects of life (Kloppenburg & Boekelo, 2019; Morstyn et al., 2018).

Data privacy and security

Data privacy concerns what constitutes energy-related information and how such information is used, accessed, and protected. Meanwhile, security emphasises on challenges related to the protection of data from potential attacks. Accordingly, there are two identified tasks associated with the selected scenario. First, the provision of secure and trusted system for information exchange (Zhang, 2017). The second task relates to the protection of consumers data to prevent unauthorised access (Bayram et al., 2014; Kloppenburg & Boekelo, 2019; Parag & Sovacool, 2016).

4.3 Conclusion

This chapter presents a scenario of decentralised energy systems that is driven by more control over supply, sustainability, and self-sufficiency to answer the following research sub-question: *What is a scenario of decentralised energy systems based on current trends and developments?*

The Plasma scenario is selected as a possible future scenario of decentralised energy systems. This scenario represents the integration of decentralised energy systems that are shaped by fast-paced technological innovations in the energy sector, allowing members within "virtually connected" communities to communicate their energy need directly. Furthermore, this scenario opens up a possibility of unlocking flexibility assets owned by their members to enable self-balancing within the networks. Therefore, technological infrastructure like local electricity generation, energy storage, and grid upgrade are the pivotal points of the Plasma scenario since these technologies influence the system boundaries, technologies, and typology of the system. Nevertheless, it is essential to emphasise on the word "virtual" for this scenario since the physical flow of electricity is still distributed through the existing infrastructure. As a result, incumbent actors do not cease to exist; instead, they operate in parallel to support and facilitate the integration of decentralised energy generation into the existing power system.

IV

Part Four: Analysis and Discussion

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5. Safeguard Energy Sector's Public Values

Chapter 4 presents a scenario of decentralised energy systems for this research. This chapter analyses the use of the distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems by applying the analytical framework proposed in Chapter 2 on the selected scenario. Therefore, this chapter aims to answer the following research sub-question:

How can the distribution of tasks safeguard essential energy sector's public values in the selected scenario of decentralised energy systems?

Following the analytical framework proposed in Chapter 2, this chapter is divided into three parts. In **Section 5.1**, the analysis of the distribution of tasks based on actors' roles and resources is presented. This section comprises of three parts, identification of actors' roles and resources, identification of new emerging tasks based on the selected scenario, and tasks allocation. Subsequently, **Section 5.2** identifies potential value conflicts that may occur due to the application of the distribution of tasks. This chapter concludes with potential government interventions to ensure the realisation of public values based on the preceding subsections **(Section 5.3)**.

5.1 Distribution of New Emerging Tasks to Safeguard Public Values

The following section analyses the distribution of tasks to safeguard public values based on roles and resources of actors as identified in Chapter 4.

Security of supply

According to the identification of new tasks in the previous chapter, there are two new tasks that are related to decentralised energy systems: (1) ensure the reliability of the systems to deliver electricity based on agreed time, quantity, and quality, and (2) manage fluctuations caused by the integration of decentralise energy generation. A number of actors are assigned for the first task. ISPs are assigned to this task because of their role as ESCo and energy supplier to their customers. The role of ESCo implies that ISPs needs to ensure the delivery of electricity according to the accepted transactions between prosumers (sellers) and consumers (buyers). Additionally, prosumers are also assigned to ensure security of supply towards the members within the network based on contractual agreements between prosumers (as sellers) and consumers (as buyers). This assignment is due to their role as producers for their own consumers as well as their resources (e.g., distributed energy resources and access to ISPs services). Nevertheless, the use of existing network implies that each member in the network is required to balance their own energy supply and demand in order to avoid any disruption on the grid (program responsibility). In the selected scenario, the ISPs have a contractual agreement with BRPs to carry out program responsibility for each member in the network. As a result, BRPs are assigned to safeguard security of supply due to their role as the balance responsible party and their financial feasibility (the ownership of a large flexible portfolio).

The second task, managing fluctuations caused by energy trades between peers, the ISPs are assigned for this task because of: (1) their role as Energy Service Companies (ESCo), (2) their access to customers energy-related information, which provides them with flexibility information, and (3) their knowledge in managing customers assets to allocate local resources efficiently. Nevertheless, the distribution of electricity that is conducted via the existing distribution networks implies that DSOs are also assigned to manage such fluctuations. This assignment is based on their role as the system operator and access to energy-related information from market participants connected to the grid network. Additionally, DSOs are also responsible for overseeing transactions or orders occurred in the network to maintain the reliability of the distribution network. This task entails that the DSO is also responsible for accepting and rejecting orders in accordance with the grids' specification.

Nonetheless, there are a few distinct challenges that can be observed. For the first task, there are two challenges. First, even though ISPs do not own any energy generators, they assume a responsibility for reliable electricity delivery due to contractual agreements established between ISPs and their members. Additionally, ISPs arrange contractual agreements with BRPs to assume balancing responsibility. Nevertheless, this arrangement is expensive since the involvement of BRPs indicates that these actors must cope with huge variations of energy trades. Such variations affect the operational costs of their portfolio (e.g., energy producers contracted by BRPs), which translates to higher balancing costs charged by BRPs. As such, in the event of imbalance, prosumers and consumers are required to pay "premium" prices because their actual production and consumption deviate from the planned consumption and production, which eventually affects the affordability of this system.

The second challenge relates to the prosumers, in the event of failure in delivering the agreed amount of volume at an agreed time, a question may arise about whether prosumers can safeguard the security of supply due to stochastic nature of renewable energy, a question may arise about the eligibility of prosumers to safeguard security of supply particularly because prosumers are small-scale producers with limited capacity. The third challenge, ISPs and DSOs are responsible for managing fluctuations caused by the integration of decentralised energy generation. Similar to the first task, there are some challenges that are observed with this arrangement. ISPs rely on their customers assets in order to perform balancing within their own network during the delivery of electricity. Nevertheless, in the event where imbalance occurs, it implies that ISPs are unable to deliver services that they are paid for, raising a question about at which level they can be assigned to manage fluctuations caused by renewable energy production. For DSOs, the challenge emerges in the event that they could not cope with the fluctuations of renewable energy production due to limited flexibility available in the network. If curtailment is required, issues may arise because of adverse effects on actors where the curtailment is applied.

Affordability

Affordability relates to the provision of affordable electricity. In essence, this can be related to the structure of electricity bills for the distribution of tasks. In this scenario, energy trades and balancing services are part of the energy bills; therefore, electricity bills are assumed to include: energy consumed, the energy produced, network charges, and services. As mentioned in the previous section, the costs of energy produced and consumed are influenced by the delivery of electricity based on the accepted orders between prosumers and consumers. Therefore, ISPs are assigned to ensure low electricity price due to their role as ESCo and their resources such as access to members energy-related information, knowledge in managing a balance between energy supply and demand, and networked governance (relationship to other parties in the market).

Network charges concern the costs associated with the network operations of the existing infrastructure. Therefore, DSOs are assigned to ensure affordable network charges, which in turn reduce the electricity price. These actors are assigned because of their role as the system operator and their resources such as physical grid infrastructure and financial resources as well as other non-tangible resources, for instance, access to information provided by other market players, knowledge in grid management, and relations to other actors in the systems. The last component of the electricity bills is services. The service costs are associated with the balancing services performed by BRPs as well as the subscription costs that are charged by ISPs to use their services. Consequently, ISPs are assigned to ensure the provision of low service costs. This assignment is due to their role as ESCo and their resources related to the delivery of their services such as the ownership of online platforms and technical infrastructure offered to their customers in order to allocate resources within the networks.

Although the use of the distribution of tasks is able to allocate tasks according to actors roles and resource, there are some challenges that may arise. Particularly because multiple actors are responsible for a certain task, but their operation may negatively affect one another. To exemplify, ISPs are responsible for ensuring the balance between supply and demand during the delivery of electricity to minimise imbalance. However, they may not be able to continuously balance energy supply and demand because of the stochastic nature of peers in the network. As a result, possible imbalance may occur during the delivery of electricity. In this situation, they have negative impacts on network charges, which affect the ability of DSOs to fulfil the task of providing affordable electricity. As this case will occur more often in decentralised systems, the next question is how the government fulfils its residual responsibility to intervene when public values are not sufficiently delivered.

Environmental sustainability

The environmental sustainability is associated with the tasks of promoting efficient use of energy to reduce dependence on fossil-fuelled power plants and the developments of decentralised energy systems that consider the effects of technologies on the environment. With regard to the first task, energy efficiency is associated with the reduction of energy required to produce and transport energy. Within this scope, it indicates that this task is related to the provision of technological infrastructure and innovations in order to support the integration of decentralised energy generation into the power systems. Following this line of reasoning, the ISPs and DSOs are responsible for this task. ISPs are assigned because of their role as ESCo as well as their resources, such as access to the customers energy-related data and knowledge in managing the balance between energy supply and demand. DSOs assigned to this task due to its role as the system operator and their resources such as physical grid infrastructure, technical knowledge, and financial means to support the integration of decentralised energy generation into the existing power system. Meanwhile, the second task may imply multiple meanings. The first one relates to the technical developments of renewable energy that needs to take into account the availability of raw materials. In the provided scenario, ISPs, as ESCo, provide technological infrastructures such as energy storage and smart monitoring devices to their customers. Consequently, ISPs are assigned to this particular task. This assignment also relates to their resources in the knowledge of their own products and, therefore, they are able to take environmental impacts into account while designing or upgrading their products.

Based on the aforementioned paragraph, there are a few challenges that may arise. First, the assignment of DSOs to support the integration of decentralised energy generation into the existing power system may result in an adverse effect for this actor. This issue arises because this integration indicates that a large dispatchable reserve is required to ensure the balance on the grid. This reserve is normally purchased from fossil-fuelled plants. Accordingly, there is an increase in dependence on non-renewable energy sources. Therefore, there is a need to expand understanding of how actors are able to safeguard public values when they are responsible for multiple values at once. Second, the environmental sustainability of decentralised energy systems does not only reside in the technological innovations realm but also in the required spatial area to meet the energy demand. To date, the requirements for renewable energy surface area is still way higher compared to the non-renewable energy. To illustrate, the power densities[1] of natural gas, solar, and onshore wind is 482.1, 9.7, and 2.02 respectively (van Zalk & Behrens, 2018). These numbers imply that solar energy requires almost 50 times space than natural gas to be able to generate the same amount of energy.

In both challenges, the governments involvement is required to ensure the protection of environment sustainability. For the first case, the government is required to distribute responsibility among actors based on their contribution to the adverse effects, instead of centring the responsibility to specific actors in the energy systems. This also implies that there is a need for knowledge transfer from the incumbent to new emerging actors. For the second case, it indicates that the government, as a regulator, has a role in defining the spatial planning, the government is responsible for integrating surface area required for the development of renewable technology in order to meet the target that has been agreed upon.

Distributive justice

There are three primary tasks associated with the value of distributive justice to develop energy systems that promote: (1) equitable distribution of costs including negative effects based on their contribution, (2) fair distribution of benefits from renewable technologies, and (3) equal access to distribution networks. The first task of distributive justice is related to the operation of decentralised energy systems and energy systems as a whole. Within the decentralised energy systems, ISPs are assigned for this task. This assignment is primarily caused by their role as ESCo and their ownership of technical infrastructure and innovations used to provide services to their members. In a decentralised setting, their role and resources enable them to develop market and pricing mechanisms which account for the contribution of members in delivering energy services (or at times of failure).

Meanwhile, in the energy systems, DSOs are assigned to this task because of their role and resources as the system operator. Here DSOs are expected to act in the public interest by

[1] The average electricity produced in one horizontal square metre of infrastructure (van Zalk & Behrens, 2018).

accounting for costs and benefits (or drawbacks) of different activities conducted via the distribution networks. For the second task, fair distribution of benefits from renewable technologies relates to equitable opportunities to innovations (e.g., distributed energy resources and infrastructure) and the opportunity of consumers to become prosumers in order to achieve, for example, economic welfare. In essence, this task relates to the provision of affordable technological innovations. Self-evidently, ISPs are assigned to ensure affordable prices on technological innovations offered. This assignment is because of their role as ESCo and their resources in the developments of technological innovations.

The third task relates to fair access to the distribution networks. In the case of decentralised energy systems, it implies that prosumers and consumers are able to connect to the distribution grid without any discrimination. Since DSOs, as the system operator, provide connection points to the distribution networks, DSOs are responsible for this task. Nevertheless, DSOs are not the only actor that is assigned to this task. Recent developments in renewable energy generation show the need for government involvement to ensure that each consumer has a right for a connection point in the grid (see, e.g., ACM, 2019b). Therefore, the government is assigned to this task due to their role in the execution and fulfilment of energy policy.

According to the aforementioned paragraphs, there are a few distinct differences between the first and the second tasks. In the first task, the development of equitable distribution of outcomes from the point of view of providing fair and equitable market and pricing mechanisms results in the fulfilment of the assigned task. However, this perspective is only limited to the technical side of this task. In an opposite manner, the second task raises a few questions in relation to whether the distribution of tasks can safeguard distributive justice. This is primarily because of the possible negative effects on ISPs. For the ISPs, fair distribution of benefits may indicate the need to facilitate the provision of affordable technological innovations. However, providing affordable innovations is not a simple matter because the ability of consumers to procure such technologies depends on their characteristics, such as level of income or spatial availability. In this sense, the government is required to be involved in the realisation of this task. This is due to their role as a regulator and their resources such as incentives to stipulate cheap prices for technological innovations in the energy sector and, therefore, increase accessibility to technological innovations.

Procedural justice

Procedural justice relates to transparency in the provision of energy service and the inclusion of all parties in the decision-making process. In the context of decentralised energy systems, transparency relates to the distribution of information to provide the members with an opportunity to participate in energy services provided by ISPs. Therefore, ISPs are responsible for this task due to their role as ESCo and their ownership of online platforms that are used by both prosumers and consumers to communicate their commercial products. In the context of the power system as a whole, transparency relates to non-discriminatory access to data, which promotes fairness in the electricity markets. In other words, all market participants are able to compete on equal footing. Therefore, DSOs, as the system operator, is assigned for this task. DSOs act as neutral market facilitators to accommodate energy service in the distribution networks. This is supported by their ownership of distribution networks, which allows them to perform network operations, providing relevant network information to all market parties. This information enables market participants to provide their commercial services.

Nevertheless, this market-centric approach implies that there is a need for the governments involvement to ensure fair competition and clear division between regulated and commercial parties. Consequently, the government is responsible for assuring the execution of regulatory frameworks and the provision of rights to participate in any energy-related activities. This assignment indicates that the government does consider not only actors that are involved in decentralised energy systems, but also those who are not involved in such systems.

Autonomy

Autonomy relates to the provision of information and ICT infrastructure that enables the customers to make their decision-making standing and promote freedom of choice as such, they believe that the systems will help them to achieve their goals. In the context of decentralised energy systems, the operation of decentralised energy systems that utilises the existing infrastructure and mainly occurs in the information layer implies that a few number of actors are responsible for this task. As the system operator, DSOs are assigned for this task because the operation of decentralised energy systems requires grid upgrade such as smart metering systems on the connection points. The grid upgrade allows reliable metered data which opens the door for energy services offered by ISPs. Additionally, ISPs are assigned to this task because of their role as ESCo and their resources such as online platforms and technological infrastructure offered to their customers. This assignment implies that ISPs are required to accommodate individual preferences and participation in the market in order for them to make their decision-making standing.

Nevertheless, the emergence of ISPs that are involved in many energy-related activities such as the provision of online platforms, technical infrastructure, or realisation of energy services (e.g., energy trading and self-balancing services) indicate that the governments involvement is required to ensure freedom of choice. For example, prosumers and consumers can exist the systems on their will. Additionally, it is important to raise possible conflicting values that may occur with the grid upgrade. The requirement for smart metering systems at the connection points indicates significant potential investments on the distribution networks. Since consumers (including ones who are not involved in decentralised energy systems) bear the cost of technological innovations, it contradicts the consideration of affordability and procedural justice.

Data security and privacy

Data security and privacy are related to two primary tasks, i.e., providing a secure and trusted system for information exchange and protection of consumers data to prevent unauthorised access. In order to identify actors assigned to this task, it is imperative to consider which data are collected and what they are used for. According to the actors' relationships presented in Figure 4.1, three types of data are being exchanged, data from installing a smart metering device at home, data from the smart metering device at the connection point, and data from and to DSOs for the provision of energy services by ISPs. As a result, multiple actors are responsible for this task. First, ISPs are responsible for those tasks because of their roles as ESCo. This role allows ISPs to provide technological innovations such as online trading platforms and technological infrastructure to their members, which are the primary focus of data security and privacy. Second, DSOs are assigned for this task because of their role as the system operator who collects data from connection points for different purposes such as consumption data for billing or network operations. Nevertheless, a vast amount of data collected indicate the need to ensure that privacy is protected, preventing unauthorised access to personal data. As a consequence, the government needs to ensure that data privacy is safeguarded and appoints a proper regulatory body to ensure the execution of regulatory frameworks.

Summary

Table 5.1 shows a summary of the distribution of tasks based on actors' roles and resources.

Table 5.1: Summary of the Distribution of Tasks to Safeguard Public Values based on the Roles and Resources of Key Actors

Public Values	Tasks	Actor(s)	Role(s)	Resource(s)
Security of supply	Ensure the reliability of the systems to deliver electricity based on agreed time, quantity, and quality.	Independent Service Providers (ISPs)	Energy Service Company (ESCo), Energy Supplier	Access to customers' information, technical knowledge in energy management, financial resources.
		Balance Responsibility Parties (BRPs) (based on contractual terms)	BRP	Financial resources and ownership of large portfolio.
		Centralised energy producers (indirect relationship due to the involvement of BRPs)	Producer	Ownership of power plants.
		Prosumers	Producers	Ownership of distributed energy resources (solar panels, energy storage, and home automation), financial resources, access to services provided by ISPs.
	Manage fluctuations caused by the integration of decentralised energy generation and energy trades.	ISPs	ESCo	Access to customers' information, technical knowledge in grid management for efficient allocation of energy, financial resources to deal with fluctuations.
		Distribution System Operators (DSOs)	system operator	Physical grid infrastructure, financial resources, technical knowledge in grid management, information from market participants for network operations, financial resources for grid planning and operations.
Affordability	Ensure low energy price.	ISPs	ESCo	Access to customers' information, technical knowledge in grid management, access to technical infrastructure offered to their customers.
		DSOs	system operator	Physical grid infrastructure, technical knowledge in grid management, information from market participants, connections to all market participants.
Environmental sustainability	Promote integration of decentralised energy generation.	ISPs	ESCo	Access to customers' information, technical knowledge in grid management and energy efficiency, access to technical infrastructure offered to their customers for efficient allocation of resources.
		DSOs	system operator	Physical grid infrastructure, information from market participants, knowledge in network operations.
	Developments of decentralised energy systems and their components that consider environmental impacts.	ISPs	ESCo	Knowledge about their own products and services (both physical infrastructure and technological innovations).
		Government	Regulator	Regulatory frameworks, public funds.

Public Values	Tasks	Actor(s)	Role(s)	Resource(s)
Distributive Justice	Develop equitable distribution of costs including negative effects based on each individual's contribution.	ISPs	ESCo	Ownership of online platforms and access to energy-related data from customers as well as DSOs, knowledge in energy management.
		DSOs	system operator	Knowledge in network operations and planning, access to energy-related information from commercial market participants connected to the distribution networks.
	Develop a fair distribution of benefits from renewable technologies (provision of affordable technological innovations).	ISPs	ESCo	Ownership of products supporting decentralised energy systems (including the provision of technological infrastructure and online trading platform), financial resources.
		Government	Regulator	Regulatory frameworks, public funds.
	Ensure equal access to the distribution networks.	DSOs	system operator	Physical grid infrastructure (manage grid access point for all connected parties), financial resources.
		Government	Regulator	Regulatory frameworks (facilitate disputes for a grid access point), public funds.
Procedural Justice	Ensure transparency in the provision of energy services.	ISPs	ESCo	Ownership of online platforms and access to energy-related data from customers as well as DSOs.
		DSOs	system operator	Information on proper network operations and planning.
	Ensure the inclusion of all parties in the decision-making process.	Government	Regulator	Regulatory frameworks.
Autonomy	Develop systems that promote freedom of choice.	ISPs	ESCo	Ownership of online platforms and technological instruments used to support the operation of decentralised energy systems.
		DSOs	system operator	Physical grid infrastructure and access to information via metered reading.
		Government	Regulator	Regulatory frameworks.
Data security and privacy	Provide secure and trusted system for information exchange.	ISPs	ESCo	Ownership of online platforms and knowledge in energy-related data management from customers as well as DSOs, financial resources.
		DSOs	system operator	Knowledge in energy-related data management and access to the data hub.
	Protect consumers data to prevent unauthorised access.	ISPs	ESCo	Knowledge in cybersecurity (generally applied in the preparation, operation, and development phases).

As shown in Table 5.1, Independent Service Providers (ISPs) and Distribution System Operators (DSOs) are responsible for many tasks associated with specific public values. As a consequence, these two actors are responsible for the realisation of multiple public values, and most public values are shared among these two actors. In this particular case, it can be justified that the centralisation of public values among these two actors is caused by their roles and resources supporting the goals and functionalities of decentralised energy systems. To illustrate, ISPs hold the role of Energy Service Company (ESCo) to the members in their network. In the selected scenario, this role indicates that ISPs do provide not only online trading platforms for their members but also technical artefacts used to support the functionality of the systems. Consequently, the emergence of new tasks associated with each public values is highly related to their role(s) and resource(s) in the decentralised energy systems.

Additionally, the operation of decentralised energy systems that depends on the existing grid infrastructure creates interrelated tasks between these two actors to realise public values. For example, to deliver electricity via energy trading [security of supply], any transaction/order that is submitted to the online platform requires DSOs' approval. Once approved and delivered, access data from connection points (managed by DSOs) is required to provide transparent information to the members within their networks [distributive justice]. These tasks jointly build up the functionality of energy trading and thus decentralised energy systems. As a consequence, the realisation of public values from one actor may depend on how the other actor fulfils their specific tasks.

The above paragraphs bring about two different insights in utilising distribution of tasks based on roles and resources of actors. First, tasks are centrally assigned to a few actors in the selected scenario, which imply that these actors are responsible for multiple public values at once. For this selected scenario, ISPs and DSOs are responsible for most public values due to their central role in the operation of decentralised energy systems. Second, many interrelated tasks affect the realisation of public values—the fulfilment of one task affects the delivery of the other task(s). Consequently, value conflicts may occur in those situations which affect how the distribution of tasks safeguards public values. This subject is the focus of the next subsequent section.

5.2 Challenges to Safeguard Public Values

Based on the aforementioned section, value conflicts may arise because actors are responsible for multiple values or multiple actors are responsible for a certain public value, affecting the realisation of public values. The following section demarcates possible value conflicts in decentralised energy systems based on those two conditions.

5.2.1 Impacts of Shared Public Values between Different Actors

As seen in Table 5.1, multiple actors are responsible for a specific value. The aims of this section are to identify possible conflicts that may occur when a multitude of actors are responsible for a specific public value and to link those findings to the literature on decentralised energy systems.

Security of Supply

Security of supply is shared among all key actors in decentralised energy systems. For ISPs, the security of supply implies that they are able to successfully deliver electricity based on agreed time, volume, and price. Nevertheless, the ability to successfully deliver electricity depends on whether DSOs accept or reject submitted orders in order to maintain the integrity of the network. If rejection happens, possible conflicts between ISPs and DSOs may occur. This finding is in line with concerns presented by M. G. Edens and Lavrijssen (2019), Lammers and Diestelmeier (2017), Lavrijssen and Parra (2017) and Zhang et al. (2018). Additionally, prosumers are responsible for the security of supply due to their roles and resources as producers. This assignment raises a question related to whether prosumers are still responsible in the event when they cannot deliver electricity at the agreed orders due to changes in electricity production caused by the unavailability of renewable resources. This issue has also been highlighted in an article by Leal-Arcas et al. (2018b).

Affordability

Affordability is shared among actors in the network based on their influences on the costs elements that make up the electricity bills. Although each actor shares the same objective to minimise the costs associated with electricity bills, possible conflicts may arise because each actor has their own interpretation on how this value can be achieved. For ISPs, affordability is achieved when members can capitalise their excess asset via energy trading and balancing services. However, the activity of energy trading may oftentimes contradict DSOs responsibility to keep the network charges low. Hence, a conflict occurs due to the realisation of one task hampers the realisation of another task. This interpretation is correspondence with the works from Askeland et al. (2018), Gautier, Jacqmin, and Poudou (2018), and Jägemann et al. (2013).

Environmental Sustainability

Environmental sustainability is shared among DSOs, ISPs, and government. At a glance, the distribution of tasks is able to safeguard public values by spreading tasks among actors based on their roles and resources in the system. Nevertheless, value conflicts may arise because of the effects of integrating decentralised energy generation into the existing power system. One prominent example is a larger dispatchable reserve may be required to maintain the balance of the systems. However, such reserve is generally procured from non-renewable power plants resulting in a higher dependence on fossil-fuelled power plants. As a result, the integration of decentralised energy generation does not necessarily achieve environmental sustainability since it increases dependence on the fossil-fulled power plants. This finding is in line with Ueckerdt et al. (2015).

Distributive Justice

Distributive justice is shared among DSOs, ISPs, and the government. One pressing issue about distributive justice that may cause a value conflict is ensuring equal access to the distribution networks. On the one hand, DSOs are responsible for ensuring that all citizens have access to connection points. On the other hand, additional connection points with decentralised energy generation incur additional issues for the DSOs. This situation may exert them to undertake drastic measures such as grid reinforcement which will negatively affect the electricity prices as a whole. This finding is similar to the studies conducted by Jägemann et al. (2013).

Procedural Justice

Procedural justice is shared among DSOs, ISPs, and the government. The primary conflict that may arise is in relation to the second task, which is the inclusion of all parties in the decision-making process. As mentioned in the previous sections, the proposed scenario depends on the grid upgrade as well as technological infrastructure. However, the provision of grid upgrade may impact not only those who are involved in the selected scenario but also other state actors as well as other regular customers. Therefore, the government is responsible for providing equal opportunities in the decision-making processes of decentralised energy systems to avoid conflicts between a multitude of actors in the system. This importance is highlighted in several studies conducted by Guerreiro, Batel, Lima, and Moreira (2015); Steg, Bolderdijk, Keizer, and Perlaviciute (2014).

5.2.2 Impacts of Safeguarding Multiple Public Values

The analysis of the selected scenario reveals that actors may be responsible for multiple values at once. As a consequence, there is a need to understand whether these values are competing with each other (see Chapter 2). **Independent Service Providers (ISPs)** play a key role in the realisation of decentralised energy systems. Therefore, ISPs are responsible for all values identified in Section 5.1. One prominent value conflicts for ISPs are the security of supply and affordability mainly because of the involvement of BRPs in the systems. On the one hand, BRPs are required to safeguard security of supply. On the other hand, their involvements jeopardise the value of affordability.

Similar to ISPs, **Distribution System Operator (DSO)** are responsible for the realisation of all values because of their role as the system operator who operates the distribution networks. In the selected scenario, DSOs encounter many competing values because the operation of energy services provided by ISPs occurred in the distribution networks and compete with their other assigned tasks. An example of value conflicts occurs between distributive justice and affordability may also arise due to the task of ensuring equal access to the distribution networks. On the one hand, DSOs are responsible for ensuring that all citizens have access to connection points. On the other hand, additional connection points with decentralised energy generation incur additional issues for DSOs—thus causing value conflicts with affordability. This finding is similar to the studies conducted by Jacobsen and Schröder (2012); Jägemann et al. (2013).

The sections above have shed some light on value conflicts that may arise with the adoption of decentralised energy systems. In this particular case, value conflicts emerge because actors are responsible for multiple public values at once or multiple actors are responsible for a certain public values. For these particular conflicts, DSOs and ISPs are actors with many conflicting values due to their roles in the selected scenario.

5.3 Government's Residual Responsibility to Safeguard Public Values

The section above highlights value conflicts that may emerge with the application of the distribution of tasks. Since those cases will occur more frequently in decentralised systems and may have adverse effects on the delivery of electricity, the next question is how the government fulfil its residual responsibility to intervene when public values are not sufficiently delivered. This section provides an overview of government interventions to safeguard public values.

In the security of supply, the primary challenge that may arise with the use of the distribution of tasks to safeguard the security of supply is value conflicts between the security of supply, affordability, and environmental sustainability. As electricity is a basic need for each citizen, the government may require to utilise the regulatory framework to enforce the realisation of security of supply. It implies that there is a need to explicitly define the conceptualisation of security of supply and which specific actor is responsible for a particular task associated with the realisation of security of supply. Particularly because of the involvement of actors like prosumers who have limited capacity to deliver security of supply.

Another type of interventions that can be applied is facilitating access to financing and capital. In distributive justice, fair distribution of benefits indicates the need to facilitate the provision of affordable technological innovations. However, providing affordable innovations are not a simple matter as it might have negative impacts on the actor. Furthermore, the ability of consumers to procure such technologies depends on the characteristics of customers, such as level of income or spatial availability. In this sense, the government is required to be involved in the realisation of this task. This assignment is due to their role as a regulator and their resources to stipulate low prices for technological innovations in the energy sector—thus, increase accessibility to technological innovations.

Additionally, government interventions can be in the form of facilitating trade-offs. In procedural justice, the primary conflict that may arise is concerning the inclusion of all parties in the decision-making process. As mentioned in the previous section, the proposed scenario depends on the grid upgrade as well as technological infrastructure provided by ISPs. However, the provision of grid upgrade may impact not only those who are involved in the selected scenario but also other state actors as well as other regular customers. Therefore, the government is responsible for providing equal opportunities in the decision-making processes of decentralised energy systems to avoid any conflict between a multitude of actors in the system. In this particular case, government intervention is facilitating possible value trade-offs because actors operate in a setting in which regulations, markets, and interrelated public values co-exist.

Nevertheless, those choice are not without consequences. First, the use of a regulatory framework to enforce the realisation of public values may result in unintended prioritisation of public values. An example that can be drawn from the above analysis is if a certain actor is responsible for realising multiple public values (e.g., the security of supply and environmental sustainability), the realisation of public values may be skewed according to this own actor interest. Second, the use of public funds to facilitate fair access to promote fair benefits of technological innovations may entail drawbacks as it might be too costly, resulting in another issue such as inequitable spending of public funds. Third, those three interventions do not address the need to cope with value conflicts, for example, re-arranging tasks to safeguard public values. Who should be responsible for this task? These questions are the subject of the subsequent chapter.

5.4 Conclusion

This chapter deals with the analysis of the distribution of tasks to safeguard public values based on the proposed scenario outlined in Chapter 4. The analysis is conducted by applying the theoretical ground in Chapter 2 to answer the following research sub-question: *How can the distribution of tasks safeguard essential energy sector's public values in the proposed scenario?*

There are three key insights gathered from the analysis. First, the distribution of tasks results in a centrally distributed arrangement due to the use of role and resources as the grounds for assigning new emerging tasks. Accordingly, the responsibilities to safeguard public values mainly fall upon two central actors in the systems, namely Independent Service Providers (ISPs) and Distribution System Operators (DSOs). Furthermore, the use of task results in two distinct characteristics: (1) tasks are frequently interrelated which implies that the realisation of one task can only be done when the other task is successfully fulfilled, and (2) multiple actors are responsible for a specific task associated with public value. Consequently, value conflicts may arise because different actors have a different understanding of how values could be best served or the realisation of one value hinders the realisation of the other values. These findings lead to the second insight from this chapter.

Second, value conflicts arise when: (1) actors are responsible for multiple values, and (2) a multitude of actors are responsible for a specific value. In the first case, value conflicts are noticeable from two types of actors, ISPs and DSOs. The primary reason for this issue is because the realisation of one task hampers the realisation of the other tasks, known as value incompatibility. A prominent example of this finding is the tasks of integrating decentralised energy generation into the power system and ensuring low energy price. On the one hand, integrating decentralised energy generation safeguards the environmental sustainability value. On the other hand, its realisation hampers the realisation of the affordability value. In the second case, value conflicts are observed when different actors have different ideas on how public values could be best served. Such conflicts are observed in the protection of the security of supply. For ISPs, the security of supply implies that they are able to successfully deliver electricity based on agreed time, volume, and price. However, the operation of energy trading conflicts with the need for DSOs to ensure the reliability of the network. These findings bring about the need for government interventions to safeguard public values.

Third, the findings show that the government's interventions are required to safeguard public values in order to fulfil its residual responsibility. Three potential interventions can be used depending on the problem at hand. However, it is important to understand possible adverse effects that may arise with the application of a specific intervention.

6. Discussion

The previous chapter builds an understanding of the distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems. In the context of this research, the application of distribution of tasks to safeguard essential energy sector's public values requires considerable government interventions to ensure the realisation of public values. This chapter synthesises the presented analysis by discussing the obtained results from a broader perspective. It identifies lessons learned that are relevant to the problem at hand and theoretical grounds presented in Chapter 2, focusing on some persistent issues for the application of the distribution of tasks to safeguard public values. Therefore, the objective of this chapter is to answer the following sub research question:

What are the unresolved issues of utilising the distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems?

To answer this sub-question, this chapter first revisits the limitations and choices made in this research (**Section 6.1**). This step is important to provide well-considered discussions on the outcomes of the analysis presented in Chapter 5 by taking into account the choices and limitations of this research. Following the discussion of the limitations of this research, **Section 6.2** discusses the feasibility of the proposed scenario. **(Section 6.3)** presents insights and unresolved issues drawn from the analysis in Chapter 5.

6.1 Limitations of this research

The limitations of this research are related to the choices of the analytical framework, the scope of this research, and other limitations that are observed during the process of this research. As these limitations affect the result of the analysis; therefore, it is important to address these limitations before discussing the outcomes of this research and their implications. This section is divided into two parts: (1) limitations of the analytical framework including the key concepts used in this research (**Section 6.1.1**), and (2) limitations caused by the scope of this research (**Section 6.1.2**). A complete overview of limitations and choices made for this research is available in Appendix A.

6.1.1 Analytical Framework

In this research, the analytical framework is developed by utilising three key concepts: (1) distribution of tasks, (2) public values, and (3) safeguard public values. These three concepts take place in the decentralised energy systems and are used to structure the analysis. Nevertheless, some choices are made in order to use them in the study. The following paragraphs explain the choices and limitations of each key concept in more detail.

First, the concept of distribution of tasks is rather an abstract concept without any definitive definition. Therefore, the concept of distribution of tasks is derived from the shift from a centralised to a more decentralised manner in public administration. In the field of public administration, the concept of tasks allocation is often used to achieve efficiency, effectiveness, and equity (see, e.g., Benson & Jordan, 2008; Charbit, 2011). This research adopts a similar approach for the distribution of tasks. In this research, the distribution of tasks is done based on actors' roles and resources. Additionally, a task is identified based on the conceptualisation of public values (see, e.g., , Painter et al., 2010; van Thiel & Yesilkagit, 2014; Verhoest et al., 2010). These choices limit the study of the distribution of tasks because:

1. by allocating tasks based on efficiency, effectiveness, and equity, distribution of tasks inherent certain values (in this case efficiency, effectiveness, and equity) (see, e.g., , Benson & Jordan, 2008; Charbit, 2011; Corrà, 2014),
2. identification of tasks based on the conceptualisation of public values relies on the level of abstraction of public values. Therefore, the identification of tasks is limited to the conceptualisation of public values,
3. other attributes of actors are not considered (for other actors' attributes see Doorn (2020)).

Second, public values are used in a wide range of subjects. Therefore, the definition of public values varies depending on how researchers use them. In this research, public values are defined based on public administration study and inherent two primary characteristics: (1) public values are values that are shared by the society as a whole, and (2) public values require the state's involvement for their protection and realisation. These characteristics are applied in the context of the energy sector to identify which public values are considered essential in the *current* energy sector. As a consequence, the identified public values may not be applicable in another field of study. For instance, what matters in the energy sector may not be considered as public values in other sectors (see, e.g., Charles et al., 2007). Furthermore, public values are treated equally, and no prioritisation is made. As a result, this research may undermine potential changes of the public values due to the transition towards decentralised energy systems because they are consciously overlooked.

Third, within this study, the distribution of tasks is expected to safeguard essential energy sector's public values in decentralised energy systems. This notion implies that the distribution of tasks safeguards public values when tasks associated with each public value are successfully delivered. Consequently, there are a few limitations:

1. If an actor faces one or more challenges to successfully deliver task(s) associated with a certain public value, this research considers that the distribution of tasks is unable to safeguard that specific public value. Here, the challenges are limited to value conflicts faced by actors

in the systems.

2. Conflicting values may occur due to: (1) the realisation of one value may hinder the realisation of other value or (2) multiple actors are responsible for a specific value (competing tasks associated with a certain public value). However, this research does not take into account which value conflicts are more important than others and which values should be prioritised in the event of value conflicts.

Although those limitations restrict the use of the study, distribution of tasks is selected because this research does not aim to provide a solution rather to raise some issues that may emerge from using the distribution of tasks to safeguard public values. An **example** that can be drawn from the analysis: prosumers are assigned to safeguard security of supply due to their role and resources as energy producers. However, their generated electricity is stochastic in nature. As such, it remains unknown how they are accountable for safeguarding security of supply without addressing other values that are considered important to them (e.g., affordability).

6.1.2 Scope of this research

Similar to the analytical framework used in this research, it is important to understand that different scope may entail different results since this research is limited to a number of factors such as the selection of public values, selection of trends and developments, and other assumptions used to build the scenario. The following section describes how those factors limit the outcomes of this research.

First, this research only focuses on a scenario derived from trends towards decentralised energy systems in the Dutch energy sector. There are two primary limitations used for this research that influence how a scenario of decentralised energy systems looks like. First, the selected scenario is developed according to the need for self-sufficiency, sustainability, and more control over supply. As a consequence, other aspects, such as economic feasibility, is overlooked. An example from the analysis: The involvement of other commercial actors such as centralised energy producers and BRPs have negative impacts on the electricity prices paid by costumers, for example, costumers are required to pay "premium" price when their consumption or production deviates from the agreed orders. Second, data related to the operation of energy trading, actor arrangements, and resources are, at times, limited. As a result, the study is conducted in a less detailed manner and, therefore, this research should not be interpreted in a more explicit that they are. Furthermore, the scenario described is limited according to the energy services provided to the customers within the networks and their effects on the actors arrangements. In reality, the energy systems are more complex with a different degree of interactions between actors in the energy systems. More elaborate limitations applied to this research can be found in Appendix A.

Second, not all public values and actors are included in this research. For the public values, only those deemed essential in the Dutch energy sector are included (see Chapter 2). This choice implies that no matter how decentralised energy systems look like, the protection of these public values are essential. In reality, other values may become essentials while others become less important (Demski et al., 2015). However, such dynamics are not considered in this research. As a consequence, to ensure that public values are fit for the purpose of the study, a validation of essential public values in the energy sector is conducted with two professors from TPM who are experts on this topic. Furthermore, the conceptualisation of public values is derived from academic literature in the energy sector. A complete literature review on public values can be found in Appendix B. For the actors, the selection of actors is according to the requirement for electricity delivery and additional services offered by the systems (see Chapter 2 and Chapter 4). Although this selection may restrict the identification of actors, the selected actors for the analysis represent fundamental actors and new emerging actors existing within the energy value chain. Therefore, the inclusion of these actors is deemed sufficient for the study.

Third, the dimension of socio-economic characteristics of the consumers and prosumers are not taken into account. It indicates two important limitations: (1) the current trends and developments in the Dutch energy system would stay the same regardless of what happens in society. In reality, prosumers and consumers are rational actors. Their decisions to join decentralised energy systems oftentimes depend on their own characteristics such as level of income or economic benefits of decentralised energy systems. Therefore, the outcomes of this research are rather limited if one would use them for understanding the effects of those factors in the distribution of tasks to safeguard public values; (2) actors are not specified based on their socio-economic characteristics. To illustrate, prosumers are considered prosumers when they consume and produce their own electricity. In practice, the ownership of distributed energy resources is diverse, which implies a high-level variation of prosuming activity (Karakaya & Sriwannawit, 2015; Rai, Reeves, & Margolis, 2016; Yaqoot, Diwan, & Kandpal, 2016).

6.2 Lessons from the Proposed Scenario

As mentioned previously, the scenario is built according to the need for sustainability, self-sufficiency, and more control over supply. As a consequence, the analysis shows that the selected scenario is considered an "expensive" scenario of decentralised energy systems. The following section discusses the outcomes of the analysis by taking into consideration the choices made for the research based on three primary constraints: (1) economic, (2) regulatory and (3) social perspectives.

Economic Challenges

The design of the proposed scenario based on limited identified drivers undermines other aspects that make up the electricity systems. Consequently, the exclusion of these aspects makes the "visibility" of some public values increase during the analysis. The first example relates to the use of existing infrastructure and technological infrastructure offered by ISPs to distribute energy. As discussed in Chapter 1, the use of existing infrastructure has multiple adverse effects on other actors such as system operators and other parties connected to the grid. According to McKenna (2018), while decentralised energy systems are beneficial, the systems give a much lower contribution to the costs of grid infrastructure compared to the negative effects they cause, which becomes apparent in the analysis. For example, the operation of energy trading executed in the grid network has negative impacts on network charges, which influences the ability of system operators to safeguard different public values such as affordability or security of supply. Since network charges are generally shared between all end-users based on their unit electricity purchased, overall network costs may increase, which will put burdens on consumers (Jägemann et al., 2013).

The second example concerns the integration costs of renewable energy generation, which account for back-up cost and balancing cost. First, ISPs are assumed as independent players without any capacity to generate electricity (i.e., they do not own any power plants); therefore, they are required to have contractual agreements with other commercial parties like Balance Responsibility Party (BRPs) to ensure security of supply (see Chapter 4). Nevertheless, the involvement of BRPs is not without consequences. Their involvement in supplying electricity accounts for variability costs of renewable energy generation, which are: (1) additional capacity required to ensure security of supply in the event when energy production is lower than demand, and (2) costs associated with the shift from baseload to peak generation (Bruninx et al., 2016). These two variables influence the imbalance costs charged to ISPs, affecting the economic value of such a scenario. Accordingly, members are required to pay "premium" prices when their actual energy usage deviates from the planned consumption. With regard to balancing cost, a larger dispatchable reserve is required in order to account for the unpredictability of renewable energy generation and, therefore, secure the energy system (see Chapter 1 and Chapter 4). However, allocating and activating those kinds of reserves come at a cost (see, e.g., Yousif et al., 2019). Consequently, the additional back-up cost and balancing cost in the proposed scenario raises a question on the economic feasibility of the systems.

Another important cost is the use of government interventions to drive the adoption of decentralised energy systems. According to the analysis, the transition towards decentralised energy systems may lead to government interventions to safeguard public values. The primary reason for such an outcome is the emergence of value conflicts that hampers actors abilities to discharge their assigned task(s), influencing the realisation of public values. As a consequence, the government has to be involved in order to fulfil its residual responsibility—interventions taken to safeguard public values when the selected mechanism fails to realise or protect public values (Corrà, 2014). Nevertheless, government interventions such as rules, subsidies, or facilitating trade-offs required to ensure the realisation of public values are costly (Charles et al., 2007; De Ridder, 2010). Therefore, this outcome raises a concern about whether decentralised energy systems are actually beneficial for society as a whole or only a part of society, particularly with regard to the unequal use of public funds.

To conclude, the aforementioned paragraphs discuss economic challenges that may arise based on the outcomes of the study. First, the use of existing grid infrastructure has negative impacts on the network charges, which affect the affordability of the electricity. Second, the economic values of energy services offered by ISPs such as energy trading or balancing services are arguable due to additional costs associated with the operation of the systems. Third, the involvements of the government in order to ensure the realisation of public values might induce additional costs that should be taken into account.

Regulatory Challenges

The scenario is built under the assumption that ISPs provide legal requirements (e.g., licensing requirements) for the members to trade their energy products actively. Within the current regulatory framework, such an assumption contradicts the current practice in the Dutch energy sector. For example, the Electricity Act 1998[1] regulates an obligatory licensing requirement for each energy supplier who wishes to supply energy to other consumers. Consequently, each prosumer who wishes to sell their own energy products within the networks is required to obtain such a license from ACM. Although it is theoretically possible, they are required to indicate that they have the minimum organisational, technical, and financial attributes to perform their tasks as energy suppliers, restricting prosumers to obtain such a license (see, e.g., Butenko, 2016). More importantly, they have an obligation to supply any consumer without bias. Such requirements contradict with the value propositions offered by the Plasma scenario since this scenario allows prosumers to set their individual's preferences, which may lead to selection bias.

With regard to the provision of energy services, the development of decentralised energy systems goes hand in hand with the trends towards local energy generation, which is motivated by, for instance, more control over supply. Nonetheless, without ancillary services such as energy storage and loads management, the scope of optimising the use of locally produced energy is limited (Luthander, Widén, Nilsson, & Palm, 2015). This is due to the fact that such technologies, especially energy storage, are still considered expensive and have uncertain effects on the claimed advantages (McKenna, 2018). Notably, if investment costs are compared against the advantage of feed-in tariff[2] or generating power from conventional resources (van der Stelt, AlSkaif, & van Sark, 2018).

Additionally, it is also assumed that the green tax for small-scale producers is eliminated to stimulate the growth of a renewable generation, which contradicts the current practice. Within the

[1] See Article 95a of the Dutch Electricity Act 1998

[2] The primary reason behind such stagnation is due to current regulation, *Salderingsregeling*, that provides no incentives for small-scale energy producers to store their energy.

current regulatory framework, small scale producers like prosumers are still required to pay energy tax. Meanwhile, initiatives like community solar farms or windmills are exempt from such a tax (GridFlex, 2018)—thus, restricting the growth of small-scale producers. Another important barrier is the current merit order for balancing services. Compared to other balancing services offered by incumbent actors, the price of balancing services from energy storage is still relatively higher due to its high capital cost, causing a restriction for its activation. Additionally, due to its limited discharge duration, energy storage is not competitive in the capacity markets (Lampropoulos, van den Broek, van der Hoofd, Hommes, & van Sark, 2018).

The above paragraphs show that regulatory adjustments are required to ensure the realisation of the decentralised energy systems. In essence, regulatory barriers are related to: (1) the current E-Act that is still based on centralised energy production, (2) the current incentive and tax schemes that hinder the technological developments of decentralised energy systems, (3) the current market rules (e.g., the merit order) that reduce the "visibility" of energy services offered by decentralised energy systems.

Social Issues

Apart from regulatory and economic constraints, there are also underlying societal issues that may arise with the adoption of the proposed scenario. The roles of new emerging actors and energy system infrastructure cannot be merely assumed. However, this research employs a simplistic approach to assign role(s) based on actors' interactions. Additionally, the perceptions of individuals towards renewable technologies have also contributed to their decision in adopting new technologies, for example, their perceived complexities (e.g., maintenance or financial constraints) of renewable technologies or expectations towards technological improvements (Karakaya & Sriwannawit, 2015; Rai et al., 2016; Yaqoot et al., 2016). This condition may emerge due to expectations of technological improvement and cost reductions (e.g. "Wait and See") that accentuate their decisions on renewable investments (Karakaya & Sriwannawit, 2015; Rai et al., 2016). Therefore, the involvement of actors in decentralised energy systems is not homogeneous. Actors may be driven by profitability influencing the willingness to be involved in energy services provided by ISPs (see, e.g., Han, Morstyn, & McCulloch, 2019; McKenna, 2018; Zhang et al., 2018). These actors are rational players, and their behaviours are often unpredictable, influencing their decision-making standing and willingness to participate in expanding low-carbon energy system (Koirala et al., 2016).

The sections above outline the challenges of the selected scenario from economic, regulatory, and social perspectives by comparing the selected scenario to the current regulatory arrangements in the Netherlands. Although the selected scenario carries many limitations, the aforementioned sections are relevant to the adoption of decentralised energy systems in the Netherlands because of two main grounds. First, the current developments of decentralised energy systems still utilise the existing grid networks. Second, trends are derived from the developments in the Dutch energy sector (see Appendix C. From the economic perspective, challenges may arise because of large interdependencies between key actors in the energy systems. Particularly if new emerging actors such as ISPs do not have any tangible assets such as power plants or large energy storage to compensate with the volatility of renewable technologies. This finding is aligned with the challenges addressed by (Bruninx et al., 2016; Yousif et al., 2019). From the regulatory perspective, challenges may arise because the current Dutch energy sector is still based on centralised energy production. For example, the current licensing requirement restricts the involvement of new actors in the system (see, e.g., Lavrijssen & Parra, 2017). Furthermore, the existence of the green tax and incentive scheme hinder the development of decentralised energy systems because these policies do not offer enough incentives for the adoption of decentralised energy systems. Moreover, the current merit order is not suitable for new technologies because high capital costs of new technologies reduce the visibility of their activation. Meanwhile, from a social perspective, social heterogeneity should be taken into account to ensure that the initiative materialises.

6.3 Lessons from the Analytical Framework

The aforementioned section establishes the implications of the selected scenario by considering choices made to build the scenario. This section focuses on the implications of the selected analytical framework on the outcomes. According to the results presented in Chapter 4, the built analytical framework shows a limited use of safeguarding public values because some persistent value conflicts that require government's involvement to safeguard public values. This finding raises questions on: (1) whether the identified roles and resources used in this research are adequate for the distribution of tasks, and (2) whether role and resources are sufficient for the distribution of tasks. This section discusses those subjects in order to identify some pressing issues that emerge with the application of the distribution of tasks to safeguard public values.

6.3.1 Changing Roles and Resources of Actors

This section discusses the results and analysis presented in this research based on the changes of two key actors, DSOs and ISPs. A comprehensive analysis of possible changing roles and resources of actors in decentralised energy systems can be found in Appendix E.

Roles and Resources of DSOs

According to the analysis, DSOs are assigned to manage fluctuations in the distribution network due to their role and resources as a grid operator. Such an assignment implies that DSOs have resources that are comparable to the system operator in order to manage fluctuations in the distribution network. Nevertheless, DSOs still face many conflicting tasks raising a question whether they have adequate resources to be assigned for a specific task associated with a certain public value. The following section discusses the outcomes of the analysis and potential additional resources for DSOs.

From the technical point of view, the use of existing infrastructure to distribute electricity has negative impacts on DSOs as they need to deal with many conflicting tasks which hamper their abilities to safeguard public values. To exemplify, DSOs are assumed to have information concerning balancing options in the distribution networks. However, it remains unknown whether such options are able to provide sufficient flexibility for grid balancing. According to Parrish, Gross, and Heptonstall (2019), little evidence is identified for customers engagement in balancing services, making its wider applicability uncertain. This uncertainty may contribute to higher dependence on fossil-fuelled power plants as well as higher network costs, reducing the feasibility of decentralised energy systems (Klaassen, 2016).

CEER (2019) suggests that enabling DSOs ability to choose the best and the most cost-efficient technology to operate the distribution network is one of the possible solutions to ensure that DSOs can perform their statutory tasks (e.g., security of supply or affordability). For example, by enabling DSOs to operate their own energy storage if its ownership does not disturb the competitive functioning of the balancing markets (Gissey, Dodds, & Radcliffe, 2018). Such an option may be applicable for this case as many different tasks are related to managing fluctuations caused by the adoption of decentralised energy systems. However, the current Dutch regulation restricts the role(s) of network operators to offer flexibility services. Primarily because the Dutch electricity market is based on four principles: freedom of connection, transaction, dispatch, and choice of resources (Lampropoulos et al., 2018). Since DSOs hold a monopoly position in the electricity market, the inclusion of network operators to offer flexibility services is considered as a threat to those principles because they will assume a commercial role. Nonetheless, network operators are the responsible party for balancing the grid. Accordingly, there is a contradiction between current regulation and the development of decentralised energy generation, which reflects in conflicting values shown in the outcomes of the analysis.

To conclude, there is a possibility that the identified resources for DSOs may not be sufficient in order to safeguard public values. The aforementioned paragraphs bring about the need to explore a potential opportunity for DSOs to operate their own energy storage facilities. Particularly, when DSOs are assigned to manage fluctuations in the network, which is the primary issue with the integration of decentralised energy generation. Accordingly, the regulatory framework should not limit a choice of technologies available to DSOs to perform their legal obligations. Nonetheless, it is imperative that DSOs have to guarantee that the use of these technologies does not lead to market disturbance or conflict with their statutory role as a network operator.

Roles and Resources of ISPs

As new actors in the energy systems, ISPs are involved in multiple activities such as the provision of technological innovations and energy services as well as management of customers' data. Consequently, these actors are expected to assume multiple roles (e.g., energy supplier and energy service company) and own a wide variety of resources such as technical knowledge in network management, technological/design, and data management and financial resources. However, similar to the DSOs, ISPs face multiple conflicting tasks which hamper their abilities to discharge the assigned tasks successfully. Before further discussion on ISPs, it is important to mention that the scenario is built under an assumption that ISPs are independent companies which are unrelated to the incumbent actors in the energy system. Additionally, as discussed in the previous section, the involvements of BRPs as well as centralised energy producers affect the feasibility of the selected scenario.

In relation to their roles and resources as energy service company, a knowledge transfer is required from the current system operator and grid operator in order to successfully deliver their services as well as supporting the energy systems and, therefore, enabling the transition towards decentralised energy systems (see, e.g., Darby, 2018; Geels, 2018). This transfer also implies that there is an additional task to define a mechanism for key performance indicators, monitoring, and knowledge sharing (Vu Van et al., 2015). This requirement raises a question on who should be facilitating the transfer of roles and resources between actors in the systems and at which level ISPs should be responsible for grid management. Apart from those findings, the used assumptions about ISPs result in an expensive scenario of decentralised energy generation mainly due to the involvement of other commercial actors like balance responsible parties (BRPs) and (indirectly) centralised energy producers in the operation of the selected scenario. Consequently, there is a need to explore which actors can take up the role of ISPs to increase the feasibility of the selected scenario.

In practice, energy suppliers are generally energy producers as well as BRPs (Universal Smart Energy Framework, 2015). Based on their current roles and resources, energy suppliers may take up the role of ISPs. However, it is important to establish that these actors are commercial parties which operate competitively in the electricity markets (M. Buth, 2018). Therefore, their involvement may depend on the profitability of decentralised energy systems. Particularly because the current Dutch electricity market is still dominated by the forward markets which accounted for 85% of the total electricity consumption[3]. Combined with the unpredictability of renewable energy sources, current incumbents like energy suppliers may not find their involvement fruitful since renewable energy generation may have impacts on their production facilities (Bruninx et al., 2016). Consequently, there is a need to identify potential collaborations between actors to deliver energy services in

[3]Bilateral/forward market emphasises on long-term duration via Over-the-Counter (OTC) contracts or future exchanges. This market is generally used by large consumers (with connections bigger than 3x80 Ampère) to buy electricity directly from the energy producers. Electricity prices and duration of these contracts are generally kept confidential between producers and consumers.

decentralised energy systems.

Deriving from the above cases, this section highlights that significant changes in the roles and resources of key actors in decentralised energy systems are required in order to increase the feasibility of the decentralised energy systems. This finding implies two possible options: (1) transfer of roles and resources among actors, or (2) new roles and resources emerge as a result of transition towards decentralised energy systems. Nevertheless, the changing of roles and resources of actors is not a simple matter. Instead, it requires multiple involvements of actors with diverging activities and interests. Therefore, there is a need to define and facilitate the changing of roles and resources between actors in order to sufficiently support the transition towards decentralised energy systems.

6.3.2 Efficient, Effective, and Fairness of the Distribution of Tasks

The concept of the distribution of tasks based on roles and resources is expected to satisfy efficiency, effectiveness, and fairness (see Section 2). This section discusses the extent to which the findings are able to confirm or contradict this expectation.

According to the analysis, the application of distribution of task shows a centralised tasks allocation between key actors in decentralised energy systems. Both ISPs and DSOs are assigned to most tasks associated with each public value due to their roles and resources as ESCo and grid operator, respectively. According to Manzoor (2014), efficiency results in a centralised manner of tasks allocation due to the idea of efficiency takes the shortest route towards the fulfilment of desired goals. The outcomes of the analysis reflect on this theoretical grounds. Nonetheless, a centralised tasks arrangement exhibits a centralised manner of public values arrangement which results in value conflicts, raising a question of whether efficiency is suitable in a decentralised setting. Primarily because value conflicts entail additional efforts from the state to ensure the realisation of public values such as government interventions, which are costly and may induce inefficiency (Charles et al., 2007; De Ridder, 2010), this finding can also be related to the concept of "moral hazard" introduced by Martens et al. (2002)—undesirable risks because actors cannot commit task(s) assigned to them.

With regard to the use of resources, resources are selected because it is unfair to assign tasks for those who do not have the means to discharge them (see, e.g., Doorn, 2020; Sheppard & Lewicki, 1987). However, assigning tasks based on resources are, at times, insufficient. To exemplify, prosumers assume the role of energy producers because they produce and trade commercial energy products (e.g., electricity generated from decentralised energy generation or energy storage). In practice, the current energy producers do not only have power generators but also the capacity to ensure that they can meet the energy demand (including financial, knowledge, or relationships with other actors in the systems) (de Vries et al., 2017; Stedin & Energy21, 2018). Consequently, the ownership of decentralised energy generation and energy storage is not comparable to those large energy producers. Since the provision of electricity has a direct impact on the end-users (e.g., buyers), it is essential to define how much contribution should prosumers have with regard to security of supply—or even assuming a role of energy producer. This is particularly important because if prosumers are required to assume full responsibility of security of supply it may contradict with how prosumers perceive the affordability value, i.e., the investment costs associated with the realisation or protection of public values (see, e.g., Leal-Arcas et al., 2018b).

Accordingly, there is a persistent question on whether it is effective and fair to assign tasks associated with the protection of public values when the availability of resources constantly affect actors' abilities to safeguard public values. Furthermore, the ownership of solar panels that differ from one another indicates the need for specifying the quantity required for tasks allocation. Without specifying the quantity required, any consumer can be a prosumer if they sell energy to other consumers regardless of their production capacity. Deriving from those two issues, by using the term "resources" without any specification results in a question whether it is fair and effective to distribute tasks based on resources (see, e.g., Kohler, Steghöfer, Busquets, & Pitt, 2014).

To conclude, the aforementioned paragraphs highlights multiple issues with utilising roles and resources to achieve efficiency, effectiveness, and fairness. First, the use of roles and resources results in a centralised manner of safeguarding public values inducing value conflicts. Second, it entails a question about effectiveness and fairness when resources are not available all the time. There are some possible explanations for this result. The idea of the distribution of tasks that is based on efficiency inherents the value of efficiency leads to centralised task allocation. Meanwhile, the level of abstraction of the resources owned by actors affects the second observation. These findings imply the need to define certain thresholds (e.g., production or financial capacity) in which actors are liable to assume a role and clarify the outcomes to be achieved.

6.3.3 To Safeguard Public Values

The government's involvement is prevalent in this research because the assumptions made that the government's interventions are considered as the only solution to safeguard public values when public values are not realised or protected. According to the outcomes, different types of government interventions are distinguished based on the characteristics of public values and value conflicts. Public values such as security of supply and affordability are often associated with conflicts due to their complexities. Therefore, governments involvements are required to safeguard public values. Such findings are expected as the three primary goals that drive every policy measure—reliability, affordability, and environmental sustainability—are often conflicting with each other (see, e.g., de Vries et al., 2017).

Additionally, these values are characterised by many interrelated tasks where the realisation of one task depends on the realisation of the other task(s). As a consequence, multiple actors are assigned to these values resulting in value conflicts. Accordingly, there is a need to put forward a more specific definition of tasks as well as their expected outcomes for each corresponding public value. Still, the use of a regulatory framework to enforce the realisation of public values may result in unintended prioritisation of public values. An example that can be drawn from the above analysis is if a certain actor is responsible for realising multiple public values (e.g. the security of supply and environmental sustainability), the realisation of public values may be skewed according to this own actor interest (Charles et al., 2007; Corrà, 2014; De Ridder, 2010). Therefore, the use of regulatory framework raises a question on how to balance between the level of abstraction and specification. In the current practice, the realisation of these three factors is indeed defined by the regulatory framework, i.e., the Electricity Act 1998. However, this regulation has been a subject to debate among many scholars due to its incompatibility for decentralised energy systems (M. Edens, 2017; M. G. Edens & Lavrijssen, 2019; Lavrijssen & Parra, 2017).

Meanwhile, values such as distributive justice or environmental sustainability imply the need for governments intervention to facilitate access for financing, i.e. subsidies or incentives. This mechanism is known as market mechanism (Bruijn & Dicke, 2006; Charles et al., 2007). The *Salderingsregeling* is an example of utilising market mechanism to safeguard public values. However, there are two primary issues with this system. First, the net metering implies that costumers who feed in electricity have a privilege to evade paying energy taxes. This is because the current energy taxes are calculated as a fixed percentage of the delivered electricity from energy suppliers to consumers. Second, this regulation does not provide enough incentives for the adoption of energy storage or energy trading. Particularly because the fixed price applied to the electricity produced by small-scale producers implies that it is beneficial for small-scale producers to feed in electricity back to the grid instead of paying for additional costs associated with energy storage. Accordingly, the use of subsidies or incentives to safeguard public values raises a question on how to balance the benefits between a multitude of actors to avoid inequitable spending of public funds while also promoting the growth of technological innovations.

The aforementioned paragraphs underline some unsettled issues regarding the choice of governments interventions to fulfil its residual responsibility in order to safeguard public values. First, there is a need for balancing between the level of abstraction and specification for safeguarding public values. The second one concerns the equity of the chosen interventions to ensure that they achieve the desired outcomes without negatively affect other parts of society.

6.4 Conclusion

By taking into consideration the analysis in the previous chapter as well as the limitations of the study, this chapter addresses pressing questions that remain unsolved with the use of distribution of tasks to safeguard public values in decentralised energy systems. Therefore, this chapter serves to answer the following sub-questions: *What are the unresolved issues in the use of distribution of tasks to safeguard essential energy sectors public values in decentralised energy systems?*

According to the analysis, many unresolved issues arise in relation to the use of the distribution of tasks to safeguard public values. These issues are categorised into three overarching aspects in order to provide clarity. First, changing roles and resources of actors implies a need for mobilising capabilities (resources) in decentralised energy systems. Therefore, there are two main aspects required: (1) facilitating the possible transfer of role(s) and resource(s) between actors in the systems, and (2) establishing agents to define and facilitate such changes. Since the distribution of tasks is based on actors' roles and resources, those two factors are considered important to ensure that actors' are able to discharge the assigned tasks in order to realise or protect public values.

The second point concerns the need for specification of public values. The identification of tasks that is based on the conceptualisation of public values shed some light on the need to clarify the public value outcomes to be achieved. This term means at which level public values are expected to be safeguarded. This aspect is particularly important because of the involvement of new emerging actors in the systems with a varying degree of resources. These diverging resources lead to the second factor in this aspect, specifying actors attributes for the assignment of a task(s) associated with public values. Here it implies that there should be thresholds in which actors are held responsible for a certain task—or even assume a certain role.

Third, by including the government in the realisation or protection of public values, some issues may arise depending on the extent of intervention. First, the balance between the level of abstraction and specification in government interventions. Second, the definition in which the government's interventions achieve the desired outcomes for society as a whole. These two factors are essential to prevent inequitable of public funds that only benefit a specific part of society.

V

Synthesis

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7. Conclusions and Recommendations

The shift towards decentralised energy systems is inevitable, and decentralised energy generation is rapidly being integrated into the existing power systems carrying both challenges and opportunities. Although the rise of decentralised energy generation is advantageous to meet the (overly) ambitious climate policy targets, the current electricity systems face many challenges due to the stochastic nature of renewable energy generation. One particular challenge that is the object of this study is the additional new tasks to safeguard essential energy sector's public values brought by the integration of decentralised energy generation. This research has the objective to provide an understanding of utilising distribution of tasks to safeguard public values in decentralised energy systems. The presented study is positioned at the intersection between social and technological aspects of the energy systems. Therefore, the following main research question is constructed and probed:

How can the distribution of tasks among key actors be adapted to safeguard essential energy sector's public values in decentralised energy systems?

To answer this above main question, multiple important aspects are investigated such as an analytical framework for assessing the problem at hand, a scenario of decentralised energy systems, and analysing the application of the distribution of tasks to safeguard essential energy sector's public values. This chapter is divided into multiple sections to address the respective conclusions drawn upon the order of the previously formulated sub-questions.

1. How can the distribution of tasks to safeguard essential energy sector's public values in decentralised energy systems be analysed?
2. What is a scenario of decentralised energy systems based on current trends and developments in the Dutch energy sector?
3. How can the distribution of tasks safeguard essential energy sector's public values in a scenario of decentralised energy systems?
4. What are the unresolved issues in the use of distribution of tasks to safeguard essential energy sectors public values in decentralised energy systems?

7.1 Building an Analytical Framework

The first sub-question aims at acquiring an analytical framework on how one can analyse the use of the distribution of tasks to safeguard public values in decentralised energy systems. To answer the research's sub-question, a clear definition of each key concept used in the research is required before defining the relationship among them — the distribution of tasks, public values, and safeguard public values. By carrying out an extensive literature review of these key concepts, the definition of each key concept is as follows.

1. The distribution of tasks means ensuring that tasks are appropriately assigned according to efficiency, effectiveness, and equity. Accordingly, the conceptualisation of the distribution of tasks is based on two primary actors' attributes—role and resources.
2. The term "public values" refers to essential public convictions that are to be achieved by public policy. Accordingly, there are two primary characteristics of the public values: (1) public values are the values shared by the society as a whole, and (2) public values require the state's involvement for their protection and realisation.
3. Safeguard public values imply that public values are successfully realised or protected.

By combining those theoretical grounds, the distribution of tasks safeguards public values when *actors are able to successfully discharge task(s) assigned to them in order to realise or protect public values*. Here, the distribution of tasks functions as the vehicle to realise or protect public values. To operationalise such a concept, three building blocks are proposed:

1. distribution of tasks, which analyses tasks allocation based on actors' role and resources. For this research, the identification of actors' roles and resources as well as tasks associated with each public value are presented in the scenario of decentralised energy systems.
2. Safeguard public values, which relates to the ability of the distribution of tasks to realise or protect public values successfully.
3. Value conflicts, which relates to challenges faced by actors to discharge their assigned tasks due to value conflicts.

This analytical framework relies on four notions. The first one holds that actors' roles and resources are able to satisfy efficiency, effectiveness, and equity (fairness). This statement means that roles and resources can be used as grounds for tasks allocation. Second, the distribution of tasks safeguards public values when actors are able to successfully discharge their assigned task(s) in order to protect or realise public values. Accordingly, the distribution of tasks is unable to safeguard public values if actors face value conflicts. Third, value conflicts occur when: (1) the realisation of one value may hinder the realisation of other value or (2) competing tasks associated with a certain public value. Fourth, the government's involvement in safeguarding public values is required when the selected mechanism failed to realise or protect public values, known as residual responsibility.

7.2 A Scenario of Decentralised Energy Systems

After proposing the analytical framework, the next step is to define a scenario of decentralised energy systems where new emerging tasks associated with the operation of decentralised energy systems become challenges to the current energy systems. Therefore, the second sub-question aims at providing a possible scenario of decentralised energy systems. In order to answer this sub-question, the scenario planning method proposed by Van Notten et al. (2003) is used. The outcome of the analysis is a scenario called the Plasma scenario. The Plasma scenario is a future energy system where prosumers and consumers are able to capitalise their flexible assets such as solar panels, energy storage, or smart appliance by participating in "virtually connected" energy communities operated by Independent Service Operators (ISPs). Furthermore, the emergence of this scenario is driven by the need to achieve sustainability, more control over energy supply, and self-sufficiency. The key characteristics of the scenario are presented below.

Three are three key enablers for the Plasma scenario. First, the declining costs of renewable energy technologies are pivotal points of the emergence of the Plasma scenario. It empowers citizens to gain more access to some parts of the energy supply chain such as production, that were unobtainable in the past. Second, the rapid growth of technological innovations such as distributed energy resources and digitalisation of energy-related data supports the transition towards prosumption activities, which is the backbone of the Plasma scenario. Lastly, behaviour changes towards energy consumption and production are the keys to enable trades of energy products between members within the "virtually connected" energy communities.

With regard to the value propositions, the Plasma scenario offers an autonomous decision on energy trading and balancing services allowing participants to capitalise on their distributed assets. Furthermore, the Plasma scenario allows each member to set their own preferences concerning their assets or energy mix—thus promoting freedom of choice. Therefore, participation in energy services is not obligatory and emphasises on the free participation of individuals who are willing to buy and sell energy products. As a consequence, this concept relies on active involvements of each member within the "virtually connected" energy communities to actively participate in the provision of energy services.

Additionally, the network structure of the Plasma scenario that adopts a peer-to-peer network allows the systems to grow or shrink in size depending on the number of participants in the network. Additionally, the technological advancements offered by the Plasma scenario enables trades of energy products that are not restricted by geographical location. Nonetheless, it is essential to emphasise that the operation of the Plasma scenario is mainly conducted at the information and financial layers because the electricity is still distributed via conventional infrastructure. This setting implies that there is no significant change in the physical grid infrastructure. Still, additional technological infrastructure such as metering devices, solar panels, and energy storage are expected to support the operation of the Plasma scenario.

Following the paragraphs above, new actors and services emerge in the Plasma scenario. The most prominent actors that appear with the adoption of the Plasma scenario are prosumers and independent service providers. At an individual level, the transition towards decentralised energy systems has resulted in the social transformation of end-users from energy consumers to prosumers. Meanwhile, independent service providers materialise to facilitate the provision of energy services such as energy trading and balancing services. Although this scenario is developed to enable more control over energy supply and self-sufficiency, it does not imply that incumbent actors cease to exist. Instead, they operate in parallel with this new system to support the operation of the Plasma scenario. A graphical representation of this scenario is presented in Figure 7.1.

Possible Challenges of the Plasma Scenario

Nevertheless, it is important to mention some challenges that may arise with the adoption of the Plasma scenario. From the economic perspective, challenges may arise because of large interdependencies between key actors in the energy systems. Particularly if new emerging actors such as ISPs do not have any tangible assets such as power plants or large energy storage to compensate with the volatility of renewable technologies. From the regulatory perspective, challenges may arise because the current Dutch energy sector is still based on centralised energy production. Additionally, the existence of the green tax and incentive scheme hinder the development of decentralised energy systems because these policies do not offer enough incentives for the adoption of decentralised energy systems. Moreover, the current merit order is not suitable for new technologies because high capital costs of new technologies reduce the visibility of their activation.

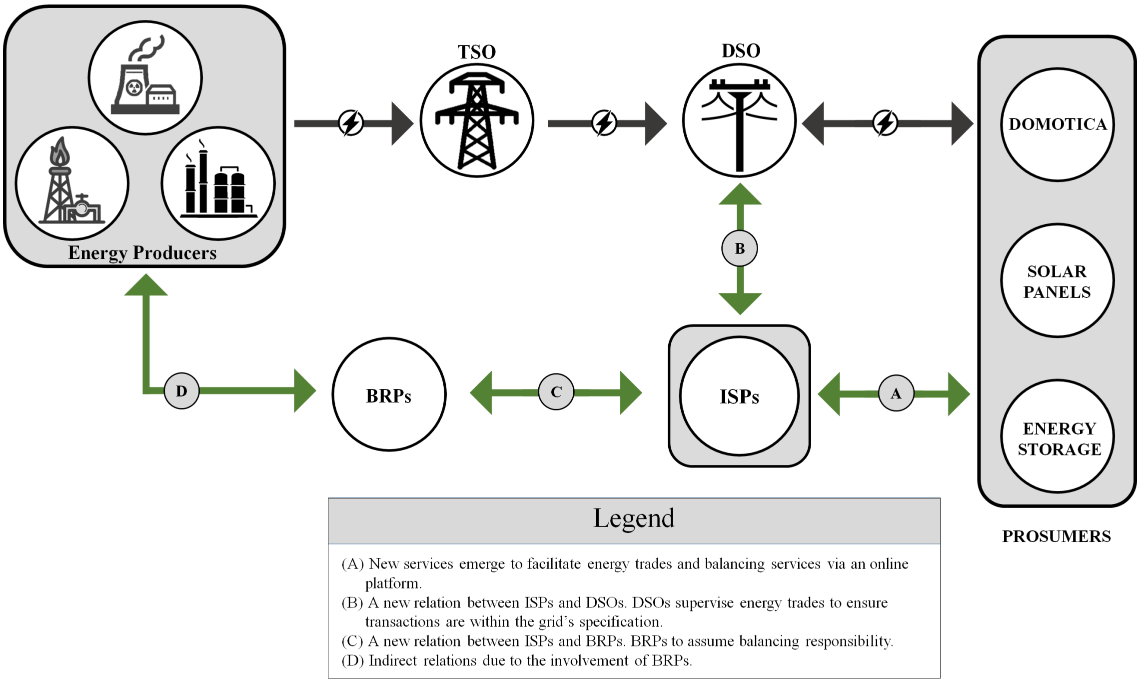

Figure 7.1: Illustration of key actors' relations in the Plasma scenario.

7.3 Distribution of Tasks to Safeguard Public Values

The third sub-question serves to operationalise the distribution of tasks to safeguard essential energy sector's public values in the selected scenario of decentralised energy systems. Therefore, the objective of this sub-question is to analyse how the distribution of tasks safeguards public values by applying the proposed analytical framework presented in sub-question 1.

The outcomes of the analysis show that the distribution of tasks can safeguard public values when the government is involved in fulfilling its residual responsibility. According to the analysis, two primary characteristics. First, a centralised tasks allocation is observed. This finding implies that tasks are distributed among two key actors in the systems, Independent Service Providers (ISPs) and Distribution System Operators (DSOs). Both actors are responsible for many tasks associated with specific public values. As a consequence, these two actors are responsible for the realisation of multiple public values, and most public values are shared among these two actors. Second, tasks are interrelated. The operation of the selected scenario that utilises existing grid infrastructure creates interrelated tasks among actors to realise public values. This notion implies that tasks jointly build up the functionality of energy services and thus decentralised energy systems. As a consequence, the realisation of public values from one actor may depend on how the other actor fulfils their specific tasks.

The above findings bring about possible value conflicts in the systems. Value conflicts arise when: (1) actors are responsible for multiple values, and (2) a multitude of actors are responsible for a specific value. In the first case, value conflicts are noticeable because of value incompatibility. A prominent example of this finding is the tasks of integrating decentralised energy generation into the power system and ensuring low energy price. On the one hand, integrating decentralised energy generation safeguards the environmental sustainability value. On the other hand, its realisation hampers the realisation of the affordability value. In the second case, value conflicts are observed when competing tasks present. Such conflicts are observed in the protection of the security of supply. For ISPs, the security of supply implies that they are able to successfully deliver electricity based on agreed time, volume, and price. However, the operation of energy trading conflicts with the need for DSOs to ensure the reliability of the network.

Due to the emergence of value conflicts with the use of the distribution of tasks to safeguard public values, the government's involvement is required to ensure the realisation or protection of public values. Depending on which public values are at stake, different types of government interventions may be required. There are three different interventions identified in this research to ensure the protection of public values: (1) formal rules, (2) subsidies or incentives, and (3) facilitating trade-offs. Accordingly, the distribution of tasks can safeguard public values when the government is involved in fulfilling its residual responsibility.

7.4 The Unresolved Issues

The previous section presents the conclusion drawn from the use of the distribution of tasks to safeguard public values in decentralised energy systems. Taking a closer look at the application the analytical framework, a set of unresolved issues can be distinguished. By highlighting different stages of the analytical framework, the following paragraph delineates multiple unresolved problems that are observed to improve the safeguarding of essential energy sector's public values.

According to the analysis, many unresolved issues arise in relation to the use of the distribution of tasks to safeguard public values. These issues are categorised into three overarching aspects to provide clarity. First, changing roles and resources of actors implies a need for mobilising role(s) and capabilities (resources) in decentralised energy systems. Two main aspects are identified: (1) a need to facilitate the transfer of role(s) and resource(s) between actors in the systems, and (2) a need to establish agents to define and facilitate such changes. Since the distribution of tasks is based on actors' roles and resources, those two factors are considered important to ensure that actors' are able to discharge the assigned tasks in order to realise or protect public values.

The second point concerns the need for specification. The identification of tasks that is based on the conceptualisation of public values shed some light on the need to clarify the public value outcomes to be achieved. This term means at which level public values are expected to be safeguarded. This aspect is particularly important because of the involvement of new emerging actors in the systems with a varying degree of resources. These diverging resources lead to the second factor in this aspect, specifying actors attributes for the assignment of task(s) associated with public values. Here it implies that there should be thresholds in which actors are held responsible for a certain task—or even assume a certain role.

Third, by including the government in the realisation or protection of public values, some challenges may arise depending on the extent of intervention. The first point relates to the balance between the level of abstraction and specification in the government's interventions. This point is important as level of specification may induce undesirable risks such as, among others, social exclusion, unintended prioritisation, and inefficiency (Charles et al., 2007; De Ridder, 2010). The second one concerns ensuring that the government's interventions achieve the desired outcomes for society as a whole.

7.5 Answering the Main Research Question

By taking into account the outcomes of the analysis as well as identifying some unresolved issues presented in the previous sections, the answer to this main question lies in understanding the conceptualisation of the key concepts used in this research—the distribution of tasks, public values, and safeguard public values.

The distribution of tasks is operationalised by considering two primary attributes of actors in the systems—roles and resources— to achieve efficiency, effectiveness, and fairness. Therefore, an understanding of the role(s) and the exact resources required to realise the role(s) are imperative. Nevertheless, a shift towards decentralised energy systems may indicate transferring of roles and resources. This factor should not be undermined and must be facilitated to ensure that actors can discharge the assigned tasks in order to realise or protect public values. Additionally, there is a need to specify at which level each actor is responsible for each task that is assigned to them in order to realise or protect corresponding public value. In other words, specifying actors' attributes for tasks allocation and elucidating the outcomes to be achieved for each actor depending on the resources they have. These aspects are important because new actors that emerge in the system carry different levels of resources, which indicate different levels of capacity to assume task(s). However, it is worth noting that by specifying the required resources and outcomes to be achieved, there is a possibility of exclusion, which may lead to debate. Accordingly, there is a need to find a balance between these two aspects. Lastly, by increasing the state's interventions through regulatory frameworks, access to capital and financing, as well as facilitating public values trade-offs, a leitmotiv can be developed that further improve the application of the distribution of tasks to safeguard public values.

7.6 Recommendations

The analysis of the distribution of tasks to safeguard essential energy sector's public values conducted in Chapter 5 and Chapter 6 reveal gaps in the formal regulatory frameworks that need to be addressed in order to support the growth of decentralised energy systems. This section puts forward recommendations based on two different perspectives, the development of decentralised energy systems and the use of the distribution of tasks to safeguard public values.

7.6.1 Recommendations for the development of decentralised energy systems

1. The emergence of new actors without sufficient resources to undertake any fundamental role(s) may hinder the development of decentralised energy systems due to many factors. From the economic perspective, the involvement of such actors results in large interdependencies to the incumbent actors that may negatively impact the economic feasibility of the systems. Accordingly, it is imperative to ensure that actors involved in the development of decentralised energy systems have sufficient resources to assume role(s).
2. The current regulatory frameworks that are used as safeguarding mechanisms in the Dutch energy sector may hinder the realisation of decentralised energy systems. This situation emerges because the development of decentralised energy systems goes hand in hand with the developments of technological innovations in the energy sector. For example, the *Salderingsregeling* which restricts the growth of energy storage at the end-user level. Accordingly, these regulatory frameworks should be adjusted in order to support the development of decentralised energy systems.
3. Regulatory frameworks shall not limit the ability of incumbent actors to utilise available technologies in order to safeguard public values, supposing that the adoption of these technologies does not harm the stability of the market or conflict with their monopoly role in the electricity system.

7.6.2 Recommendations for the use of the distribution of tasks to safeguard public values

1. The use of distribution of tasks to safeguard public values requires a deeper understanding of not only the roles and resources actors have but also their drivers and how these drivers affect the management of their resources. Therefore, socio-economic characteristics of each actor should be taken into account if resources are used as a ground for distributing tasks.
2. The conceptualisation of the distribution of tasks that are used to achieve efficiency, effectiveness, and equity contradicts the idea of decentralisation as tasks are centrally distributed,

resulting in many value conflicts. Therefore, there is a need to expand the concept of the distribution of tasks in order to achieve desired outcomes.

3. A quantification of public values may be required in order to assign a certain task(s) to actor(s) in decentralised energy systems. This specification is required to ensure that actors have required resources to discharge the assigned tasks, which in turn ensuring the realisation or protection of public values. Nevertheless, it is important to find a balance between the level of abstraction and specification to avoid inefficiency and exclusion.
4. Government interventions to safeguard public values should ensure that they achieve desired outcomes without negatively, affecting another part of society.

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8. Reflection

Just like a story, this report should also end with an epilogue. The goal of this chapter is to reflect on four subjects in this research, i.e., analytical framework, scoping, methodological choices, and the research findings. By contemplating on these four subjects, societal and scientific contributions are identified. Additionally, policy recommendations and research outlook are given.

This chapter is organised as follows. Section **8.1** presents reflection on the built analytical framework. **Section 8.2** reflects on scoping and choices used in this research, followed by reflection on methodological choices (**Section 8.3**). Following these identification, societal and scientific contributions are presented in **Section 8.4**. Meanwhile, research outlook is presented in **Section 8.5**.

8.1 Reflection on the analytical framework

The concept of distribution of tasks to safeguard public values is used in the research in order to make the problem at hand accessible and to structure the analysis of the case. There are three key concepts used in this research: (1) the distribution of tasks, (2) public values, and (3) safeguard public values. The use of these key concepts enables the study of the distribution of tasks to safeguard public values in decentralised energy systems. Nevertheless, questions may arise regarding the selection of these key concepts and if another concept could also be used, which could lead to different results. This section discusses the analytical framework used for the study and the assumptions made on each key concept as well as put a perspective on the government's intervention.

The Concept of the Distribution of Tasks

In this research, the objective of the distribution of tasks is to achieve efficiency, effectiveness, and fairness. Two actors' attributes are used as grounds for tasks allocation—roles and resources. Therefore, it is assumed that the distribution of tasks based on roles and resources satisfies efficiency, effectiveness, and fairness. However, some issues that are addressed in the previous chapter show that roles and resources do not satisfy those three primary aspects, raising a question whether roles and resources are suitable or even sufficient for tasks allocation. In the literature, there are other actors' attributes that can be used for distributing the tasks (see, e.g., Doorn, 2020). These theoretical grounds can be used for future study to explore possible combinations of actors' attributes for tasks allocation.

Additionally, by establishing that tasks allocation aims at achieving efficiency, effectiveness, and fairness, the distribution of tasks indirectly inherent those three value. Therefore, the distribution of tasks can be viewed as a form of safeguarding in its own right (see, e.g., Corrà, 2014). Nevertheless, the outcomes of this study show that the distribution of tasks does not hold against those three key values. According to de Graaf et al. (2016), efficiency and effectiveness are inherently in conflicts; for example, by working in an efficient manner might mean that the work is conducted less effectively. Accordingly, different conceptualisation should be explored to conceptualise the distribution of tasks in the context of safeguarding mechanism.

Recommendations

To sum up, the aforementioned paragraphs reflects on the conceptualisation of the distribution of tasks used in this study. There are two suggestions for future research: (1) an exploration of different conceptualisation for the distribution of tasks, and (2) the use of other actors' attributes for tasks allocation.

The Concept of "Safeguard Public Values"

Before further discussion of the problem, it is important to mention that the term safeguard public values used in this research implies that public values are safeguarded when tasks related to each public value are delivered successfully.

First, the use of tasks associated with each public value results in a question: if one task has an adverse effect on the other task, does it really imply that public values are not safeguarded? An example of such an issue is the value of the security of supply. In this value, two additional tasks are identified: (1) ensuring uninterrupted delivery of electricity in decentralised energy systems, and (2) managing fluctuations occurring in the network caused by the integration of decentralised energy generation. If the first task is fully realised because all relevant actors are able to discharge their assigned task but has an adverse effect on the second task, how does it mean for safeguarding public value?

For the second case, if a few members are responsible for a task and one fails to deliver their assigned task, is the public value not safeguarded? An example can be drawn from the task related to affordability. In the selected scenario, five elements of electricity bills are identified, i.e., energy consumed, the energy produced, network charges, taxes, and data services; and each component is assigned based on actors roles and resources. If the system operator is required to obtain a large dispatchable reserve due to trading activity affecting the affordability. Does it mean the affordability value as a whole is not safeguarded?

These two cases question the definition of "safeguard public values" employed in this research. By strictly using this term, many public values are not realised, requiring government involvement to ensure the realisation of public values, which is costly (see, e.g., Charles et al., 2007; De Ridder, 2010). Therefore, instead of relying solely on the delivery of task(s) associated with public values, the different conceptualisation of "safeguard public values" can be explored in the context of the distribution of tasks, for example, at which level safeguard is achieved or potential value prioritisation to safeguard public values.

Recommendations

To sum, this section provides a reflection of the concept "safeguard public values" employed in this research. By only adhering on the delivery of assigned tasks, two questions may arise: (1) if a task is successfully delivered and another task fails to be realised, does it really imply that public values are not realised? And (2) if a task is shared between different group of actors and one actor fails to discharge its assigned task, is the public value not safeguarded? These two questions raise some valid points on the definition of safeguarding public values employed in this research. A broader view of the term safeguard public values could be used to provide a more feasible arrangement of safeguarding public values.

Public Values and Value Conflicts

The discussion in Chapter 5 also brings multiple insights into the conceptualisation of public values. In this research, the conceptualisation of public values is derived from existing literature (see Chapter 2). This method is selected because it provides an overview of what scholars think about public values and how these findings can be applied to the concept of the distribution of tasks. For some identified public values such as procedural justice and data security and privacy, the conceptualisation of public values from literature is proven to be useful in detecting tasks associated with those public values. However, the above sections have pointed out that the abstractness of public values entails some challenges. In the distribution of tasks, the abstraction of public values leads to a question regarding whether actors are held responsible solely on resources they have or should a more specific conceptualisation offered to ensure efficiency, effectiveness, and fairness? In the second preceding section, public values entail a different number of tasks. In the event where one fails to materialise, does it imply that public values are not safeguarded? These questions bring about the importance of detailed public values in the context of this research.

Additionally, the exploration of utilising distribution of tasks to safeguard public values reveals interesting intakes from many perspectives. Actors may be responsible for multiple values at the same time or share the same values with other actors in the system. Inherently, different actors may have different ideas on which values are more important than others (see, e.g., S. Schwartz, 2013). As this research does not take into account value prioritisation, it becomes clear that many challenges may occur to safeguard public values. These findings raise issues about whether value prioritisation is beneficial for the distribution of tasks in order to advance the realisation of public values.

Another take on the value conflicts, Taebi, Correljé, Cuppen, Dignum, and Pesch (2014) suggest that there are two ways in dealing with value conflicts: (1) to adapt the technological design of decentralised energy systems components in a way that they can accommodate conflicting values (applicable for intra-value conflicts), or (2) to perform a value trade-off that decides which value should be prioritised in the design of decentralised energy systems (applicable to inter-value conflicts). However, the primary problem with both solutions is how one can measure that sufficient design or trade-offs are acceptable (Steenhuisen, 2010). This research does not take into account such possibilities. Therefore, future research should look into the possibilities of those two options in the context of the distribution of tasks.

Additionally, safeguarding public values may be realised by an unplanned societal mechanism such as the invisible hand of the market which has been prominent with environmental pollution (see, e.g., Corrà, 2014; De Ridder, 2010). Additionally, actors may also realise workable trade-offs between conflicting values that are at stake, advancing the realisation of desirable trade-offs and hinder against less desirable ones (Charles et al., 2007; de Vries et al., 2017). For example, the value of security of supply depends on the willingness to pay for a given level of security. The higher it is, the more expensive the systems are.

Recommendations

Although this research has many limitations, it sheds some light on possible issues regarding the use of public values for the application of the distribution of tasks to safeguard public values. First, the conceptualisation of public values may need to be more specific to accommodate the use of distribution of tasks to safeguard public values. Second, value prioritisation may be required in the event of value conflicts to advance the use of distribution of tasks to safeguard public values. Third, there is a need to explore possible options for dealing with conflicts with regard to the designs or acceptable trade-offs.

8.2 Reflection on Scoping and Choices

Scoping and choices have to be made to keep this research feasible. Nevertheless, making choices that fit with the purpose of the study are challenging. Some choices and scoping made for the study are discussed below. The aims of this section are to reflect on these choices and to see whether other choices would lead to better results.

The Exclusion of Civil Society Actors

This research adopts a simplistic way of describing the selected scenario through a limited number of socio-technical factors, as mentioned in Chapter 2. Thus ignoring the fact that there are possible civil society actors that drive the shift towards decentralised energy systems. For example, actors who coordinate bulk purchasing of renewable energy generation resulting in a lower price or those who facilitate different types of renewable energy generation's ownership (Bomers, Russchen, Wartena, Meeuwesen, & Salvioli, 2016; Drury et al., 2012; Huijben & Verbong, 2013; Sung & Park, 2018). In reality, these actors have shaped the socio-technical characteristics of decentralised energy systems (see, e.g., Desfosses, 2018). Such actors may increase the affordability of decentralised energy systems and should be included in the study.

Individual's Characteristics

On the individual level, the scenario is built under homogeneous assumptions, which imply that people have similar characteristics. This assumption indicates the same types of actors are treated equally. For example, if an actor is a prosumer then they will have the same characteristics. This choice is made to simplify the analysis. However, this simplification becomes an issue at the later stage of this research because it is hard to identify whether or not a prosumer, for example, is responsible for security of supply when they have limited production capacity. More importantly, this research focuses on the roles and resources (knowledge, finance, time, etc.) of actors and, therefore, the scenario is developed in such a way it can identify those two main factors for the analysis. This approach undermines the social elements of the households such as the way households use the options and chances to make any decision in undertaking any role(s) based on resource(s) they have.

New Public Values?

On the societal level, the selection of public values is based on what is currently embedded public values in the power system. Therefore, the research leaves out emerging public values that may appear as a result of energy system change. To illustrate, Demski et al. (2015) identifies comfort as a value that may become important in a decentralised manner. In the current system, the end-users are not required to "actively" manage their energy consumption and production. However, the emergence of decentralised energy systems implies that the end-users would need to actively manage their energy production and consumption, which may result in a value trade-off. Such a value is not discussed in the research. The inclusion of additional public values that may emerge with the adoption of decentralised energy systems should be taken into account as it influences the tasks allocation of actors in the systems affecting how public values are safeguarded.

Recommendations

To sum, a few recommendations can be drawn for future research. First, the inclusion of civil society actors may affect the shape and the value proposition of decentralised energy systems. Second, the exclusion of an individual's characteristics results in challenges observed in Chapter 5.

Therefore, there is a need to include these characteristics in system design. Third, new public values may become important in the future and, therefore, add complexities in safeguarding public values. Accordingly, it is important to include such values since they may influence actors arrangement.

8.3 Reflection on Methods

This section discusses the methods used in this research. The first section discusses the use of a literature review and the second part reflects upon the use of scenario development in this research.

Scenario Planning

For this research, scenario planning is used to construct a scenario of decentralised energy systems based on current trends in the energy systems. However, the scenario is not forecasted; it is a possible future and, therefore, may be contested. Additionally, it is imperative to mention that the outcome of the scenario development is difficult to validate due to limited empirical data in which the scenarios can be tested. As a consequence, the credibility of the generated scenario may, at times, be questioned. Furthermore, a balance between the level of details and the broader scope of decentralised energy systems is required to be identified in order to ensure the feasibility of the study. Since the scope of the problem is too broad, there are some issues with the identification of trends and developments. In light of this issue, a smaller scope of the problem area is recommended, for example, only focusing on a particular technological development of the systems to make the identification more manageable.

Following the identification of trends proposed in the previous section, the next step is scenario development, which decides the composition of the scenario and how the elements in the scenario are connected are presented. In this research, the scenario narrative is developed according to clustered trends in order to provide an overview of what a future scenario looks like and use it as a basis for the subsequent analysis. However, these choices are not without any consequence. Some trends identified during the preliminary analysis are omitted because those trends are out of the scope of this research for the upcoming analysis. For example, technological trends (blockchain technology) and increasing geopolitical unrest. These types of trends may be important if the research scope is different.

Additionally, the scenario is built based on the researcher's knowledge according to the literature review. Therefore, some limitation regarding its validity and credibility may affect the outcomes of the analysis. As shown in the discussion of the scenario, the scenario is not economically feasible due to some limitations applied while building the scenario. Accordingly, it is recommended to conduct scenario analysis with additional resources such as interviews or workshops to enrich the scenario and increase its validity and credibility.

Recommendations

To sum up, the use of scenario planning helps to structure the scenario analysis leading to a scenario narrative. However, it is important to narrow down the scope of the research in order to make the subsequent stages of scenario planning more manageable. Additionally, a combination of extensive literature review and another data collection method, such as workshops is recommended in order to increase the credibility of the outcomes of the scenario.

The Identification of Tasks

The identification of tasks that is based on the conceptualisation of public values is a challenging task. The primary issues are the conceptualisation of public values that oftentimes do not fit with the specification of technical requirement. This reflect to the previously mentioned recommendation to put forward specification of public values.

8.4 Academic and Societal Relevance

In scientific literature, it is revealed that new tasks associated with public values emerge as a result of transition towards decentralised energy systems. However, there is no scientific literature providing answers on how tasks can be distributed among actors in order to safeguard public values. Accordingly, challenges or consequences that entail with the application of the distribution of tasks to safeguard public values remains understudied. Therefore, this research is carried out based on three points of departure. Firstly, it addresses the research gap on how the distribution of tasks to safeguard public values can be analysed in the context of decentralised energy systems. Secondly, it explores challenges and consequences with the application of the distribution of tasks to safeguard public values. Thirdly, can the distribution of tasks be used to safeguard public values? Based on previous chapters and the aforementioned sections, the following paragraphs provide the contributions of this research.

This research proposes an analytical framework to study the application of the distribution of tasks to safeguard public values in decentralised energy systems. This analytical framework comprises of three primary key concept–the distribution of tasks, public values, and safeguarding public values. The distribution of tasks implies that tasks are allocated based on efficiency, effectiveness, and equity. Accordingly, the conceptualisation of the distribution of tasks is based on two primary actors' attributes—role and resources. Second, the term "public values" refers to essential public convictions that are to be achieved by public policy. Accordingly, there are two primary characteristics of the public values: (1) public values are the values shared by the society as a whole, and (2) public values require the state's involvement for their protection and realisation. Lastly, safeguard public values which imply that public values are successfully realised or protected. Therefore, the distribution of tasks safeguards public values when *actors are able to successfully discharge task(s) assigned to them in order to realise or protect public values*. Nevertheless, the use of this analytical ground is not without consequences. This leads to the second contribution of this research.

For the second point of departure, issues of utilising the distribution of tasks to safeguard public values are prominent. In order to explore the challenges and consequences it entails, this study is done through the lens of value conflicts. First, changing roles and resources of key actors are identified as a prerequisite for the adoption of decentralised energy systems. As a consequence, more detailed information on the resource(s) and the exact role(s) of each actor in decentralised energy systems are required. This information refers to, for example, how much electricity actors can generate or the level of financial capability to assume tasks associated with public values. Nevertheless, such information is frequently unavailable, making the use of the distribution of tasks limited. Second, the conceptualisation of each public value plays an important role in identifying task(s) that are related to the realisation of public values. This condition arises because the identification of task(s) depends on the conceptualisation of public values. However, public values are generally used in a wide variety of study, and their conceptualisation is rather abstract. As a consequence, challenges may arise when ones try to identify task(s) in a more detail manner from a rather abstract concept. Third, the definition of "safeguard public values" implies the need to specify the outcomes to be achieved by safeguarding mechanism. This specification is of great importance when dealing with large interdependencies environment like the energy sector. This is because such a sector has inherent public values that often compete with each other. Therefore, there is a need to define desired outcomes for society as a whole. Deriving from the aforementioned information, issues are related to the need for specification. However, it is important to understand that specifying may lead to undesirable risks such as, among others, social exclusion, unintended prioritisation, and inefficiency (Charles et al., 2007; De Ridder, 2010). Therefore, all these drawbacks must be taken into account.

The last point, can the distribution of tasks be used to safeguard public values? At this point, it is difficult to judge whether the distribution of tasks can safeguard public values due to many assumptions affecting the outcomes of the analysis. According to the analysis, the distribution of tasks, by itself, safeguards essential energy sector's public values to a lesser extent. First, the result of the analysis shows that a centralised tasks allocation among central actors in decentralised energy systems is observed due to the use of actors' roles and resources for distributing tasks. Accordingly, this arrangement causes a centralised manner of public values, which results in various value conflicts. As this research defines the emergence of value conflicts as an indication that actors are unable to fully deliver their assigned tasks in order to realise public values; therefore, the distribution of tasks, by itself, is unable to safeguard public values in most identified public values since this concept relies on the government's interventions to fulfil its residual responsibility to safeguard public values. However, it comes down to the definition of safeguard public values. As mentioned earlier, this study raises a need to adopt a different notion of the term "safeguard public values" because different actors with a varying degree of capacities would involve in decentralised energy systems. The next question is, would society accept such trade-offs? This question is not explored in this research.

8.5 Research Outlook

The above sections reflect on four different main areas of research—analytical framework, scoping and limitations, methodological choices, and research findings—and provide additional insights for each area. Based on these insights, the following issues are highlighted as important topics for future research.

1. The distribution of tasks is operationalised by using limited actors' attributes, i.e., role(s) and resource(s). In reality, there are many actors attributes that can be used for assigning tasks (see, e.g., Doorn, 2020). Future research should expand the use of various actors' attributes in order to understand whether additional attributes can be used to operationalise tasks allocation among actors in the system. Nevertheless, by considering more actors' attributes, it is expected that more data is required and is very time consuming as some data may not be available.
2. With regard to the conceptualisation of the distribution of tasks used in this research, which aims at achieving, efficiency, effectiveness, and fairness, it implies that this concept indirectly inherits these three values (see, e.g., Corrà, 2014). In this research, these inherent values are not quantified; rather, roles and resources are deemed sufficient to meet those three values. Therefore, it is likely that this assumption affects the outcomes of the research. Future research should look beyond these limitations in order to provide well-considered advice.
3. The term "safeguard public values" indicates the need to ensure the realisation of public values. Nevertheless, the use of tasks associated with each public value implies that some tasks may, at times, compete with each other. Therefore, exploration of the conceptualisation of "safeguard" is recommended in order to utilise this term in more diverse studies.
4. Since this research recommends a more specific conceptualisation of public values, it is suggested that future research explores the effects of a more specific value conceptualisation. For example, if a different degree of security of supply is applied (e.g., 80% vs 100%), how this level can contribute to the tasks arrangements between actors in the energy systems and what the implications are to the existing policies in order to facilitate the growth of decentralised energy systems.
5. As shown in the outcomes of the analysis, some values inherently compete with each other. Therefore, public values conflicts are inevitable. This research treats public values equally and, therefore, any public value conflicts require the government's interventions, which are costly. Additionally, trade-offs are not considered in this research because they are hard to quantify. It would be interesting to combine value prioritisation with trade-offs in order to

understand whether tasks allocation can be used to safeguard public values.

VI

Back Matters

References

Ackermann, T., Andersson, G., & Söder, L. (2001). Distributed generation: a definition. *Electric Power Systems Research*, *57*(3), 195 - 204. doi: https://doi.org/10.1016/S0378-7796(01)00101-8

ACM. (2019a). *Electricity transmission requires sweeping measures by system operator.* Retrieved 2019-08-08, from `https://www.acm.nl/en/publications/electricity-transmission-requires-sweeping-measures-system-operator`

ACM. (2019b). *Freedom to choose one's own energy supplier also on private networks.* Retrieved 2019-07-08, from `https://www.acm.nl/en/publications/freedom-choose-ones-own-energy-supplier-also-private-networks`

Albadi, M., & El-Saadany, E. (2008). A summary of demand response in electricity markets. *Electric Power Systems Research*, *78*(11), 1989 - 1996. doi: https://doi.org/10.1016/j.epsr.2008.04.002

Amer, M., Daim, T. U., & Jetter, A. (2013). A review of scenario planning. *Futures*, *46*, 23 - 40. doi: https://doi.org/10.1016/j.futures.2012.10.003

Askeland, M., Backe, S., Fagerstrøm, J., Crespo del Granado, P., Hofmann, M., Jaehnert, S., ... others (2018). Prosumers role in the future energy system.

Bax & Company. (2018). *Codeveloping the first large-scale peer-to-peer energy trading market in NL.* Retrieved 2019-04-10, from `https://baxcompany.com/insights/first-peer-to-peer-energy-trading-market-in-the-netherlands/`

Bayram, I. S., Shakir, M. Z., Abdallah, M., & Qaraqe, K. (2014). A survey on energy trading in smart grid. In *2014 ieee global conference on signal and information processing (globalsip)* (pp. 258–262). doi: 10.1109/GlobalSIP.2014.7032118

Benson, D., & Jordan, A. (2008). Understanding task allocation in the european union: exploring the value of federal theory. *Journal of European Public Policy*, *15*(1), 78-97. doi: 10.1080/13501760701702215

Blanchet, T. (2015). Struggle over energy transition in Berlin: How do grassroots initiatives affect local energy policy-making? *Energy Policy*, *78*, 246–254. doi: 10.1016/J.ENPOL.2014.11.001

Bomers, S., Russchen, B., Wartena, T., Meeuwesen, A., & Salvioli, M. (2016). *Technical and financial overview on combining solar panels with growing low revenue crops focused on the coming pilot project in Goeree-Overflakkee* (Tech. Rep.). Retrieved from http://edepot.wur.nl/408307

Bompard, E., Han, B., Masera, M., & Pons, E. (2014). Smart grid as multi-layer interacting system for complex decision makings. In G. D'Agostino & A. Scala (Eds.), *Networks of networks: The last frontier of complexity* (pp. 187–201). Cham: Springer International Publishing. doi: 10.1007/978-3-319-03518-5_9

Bouffard, F., & Kirschen, D. S. (2008). Centralised and distributed electricity systems. *Energy Policy*, *36*(12), 4504 - 4508. (Foresight Sustainable Energy Management and the Built Environment Project) doi: https://doi.org/10.1016/j.enpol.2008.09.060

Bozeman, B. (2007). *Public values and public interest : counterbalancing economic individualism*. Georgetown University Press. Retrieved from https://www.jstor.org/stable/j.ctt2tt37c

Bruijn, H. D., & Dicke, W. (2006). STRATEGIES FOR SAFEGUARDING PUBLIC VALUES IN LIBERALIZED UTILITY SECTORS. *Public Administration*, *84*(3), 717–735. doi: 10.1111/j.1467-9299.2006.00609.x

Bruninx, K., Delarue, E., Ergun, H., May, K., Van Den Bergh, K., & Van Hertem, D. (2016). Determining the impact of renewable energy on balancing costs, back up costs, grid costs and subsidies.

Butenko, A. (2016). Sharing Energy: Dealing with Regulatory Disconnect in Dutch Energy Law. *SSRN*. doi: 10.2139/ssrn.2847590

Buth, M. (2018). *Blockchain technology for peer-to-peer trading in the Dutch electricity system: from hype to reality* (Doctoral dissertation, Eindhoven University of Technology). Retrieved from https://research.tue.nl/en/studentTheses/blockchain-technology-for-peer-to-peer-trading-in-the-dutch-elect

Buth, M. A., Wieczorek, A. A., & Verbong, G. G. (2019). The promise of peer-to-peer trading? the potential impact of blockchain on the actor configuration in the dutch electricity system. *Energy Research Social Science*, *53*, 194 - 205. doi: https://doi.org/10.1016/j.erss.2019.02.021

CEER. (2019). *New Services and DSO Involvement* (Tech. Rep.). Retrieved from https://www.ceer.eu/documents/104400/-/-/ef4d6e46-e0a5-f4a4-7b74-a6d43e74dde8

Chapman, S. (2018). *Using blockchain to share sustainable energy.* Retrieved 2019-04-11, from https://www.energydigital.com/sustainability/using-blockchain-share-sustainable-energy

Charbit, C. (2011). *Governance of public policies in decentralised contexts* (Tech. Rep.). doi: https://doi.org/https://doi.org/10.1787/5kg883pkxkhc-en

Charles, M. B., Dicke, W., Koppenjan, J., & Ryan, N. (2007). Public Values and Safeguarding Mechanisms in Infrastructure Policies. A conceptual and theoretical exploration. Retrieved from https://eprints.qut.edu.au/9283

Coleman, J. (1994). *Foundations of social theory*. Belknap Press of Harvard University Press.

Corrà, A. (2014). *Contracting for public values* (Unpublished doctoral dissertation). University of Groningen. (Relation: https://www.rug.nl/ Rights: University of Groningen)

Coventry, P. A., Fisher, L., Kenning, C., Bee, P., & Bower, P. (2014). Capacity, responsibility, and motivation: a critical qualitative evaluation of patient and practitioner views about barriers to self-management in people with multimorbidity. *BMC Health Services Research*, *14*(1), 536. doi: 10.1186/s12913-014-0536-y

Darby, S. J. (2018). Smart electric storage heating and potential for residential demand response. *Energy Efficiency*, *11*(1), 67–77. doi: 10.1007/s12053-017-9550-3 de Graaf, G., Huberts, L., & Smulders, R. (2016). Coping with public value conflicts. *Administration Society*, *48*(9), 1101-1127. doi: 10.1177/0095399714532273

de Graaf, G., & van der Wal, Z. (2010). Managing conflicting public values: Governing with integrity and effectiveness. *The American Review of Public Administration*, *40*(6), 623-630. doi: 10.1177/0275074010375298

Demski, C., Butler, C., Parkhill, K. A., Spence, A., & Pidgeon, N. F. (2015). Public values for energy system change. *Global Environmental Change*, *34*, 59 - 69. doi: https://doi.org/10.1016/j.gloenvcha.2015.06.014

De Ridder, K. (2010). *Safeguarding public values in social security: A public administration perspective*.

Desfosses, D. (2018). *Jumping into the future: The transition towards a decentralised energy system in australia* (Unpublished doctoral dissertation).

de Vries, J., Correljé, F., & Knops, P. (2017). *Electricity Market design and policy choices*.

Dietz, T., Fitzgerald, A., & Shwom, R. (2005). Environmental values. *Annual Review of Environment and Resources*, *30*(1), 335-372. doi: 10.1146/annurev.energy.30.050504.144444

Dignum, M., Correljé, A., Cuppen, E., Pesch, U., & Taebi, B. (2016, 01). Contested technologies and design for values: The case of shale gas. *Science and Engineering Ethics*, *22*(4), 1171–1191. doi: 10.1007/s11948-015-9685-6

Doorn, N. (2020). *Water Ethics. An Introduction*. New York, New York, USA: Rowman & Littleeld.

Dr Ten BV. (n.d.). *Sea salt battery.* Retrieved 2019-04-11, from `https://www.drten.nl/portfolio_item/zeezout-batterij/?lang=en`

Drury, E., Miller, M., Macal, C. M., Graziano, D. J., Heimiller, D., Ozik, J., & IV, T. D. P. (2012). The transformation of southern california's residential photovoltaics market through third-party ownership. *Energy Policy*, *42*, 681 - 690. doi: https://doi.org/10.1016/j.enpol.2011.12.047

Eaton, D., Meijerink, G. W., & Bijman, J. (2008). *Understanding institutional arrangements: Fresh fruit and vegetable value chains in east africa* (No. 11]). Wageningen International.

ECN. (2017). *The supply of flexibility for the power system in the Netherlands: Report of phase 2 of the FLEXNET project* (Tech. Rep.). Retrieved from `https://www.tno.nl/media/12356/e17044-flexnet-the-supply-of-flexibility-for-the-power-system-in-the-netherlands-2015-2050-phase-2.pdf`

Edens, M. (2017). Public value tensions for Dutch DSOs in times of energy transition. *Competition and Regulation in Network Industries*, *18*(1-2), 132–149. doi: 10.1177/1783591717734807

Edens, M. G., & Lavrijssen, S. A. (2019). Balancing public values during the energy transition How can German and Dutch DSOs safeguard sustainability? *Energy Policy*, *128*, 57–65. doi: 10.1016/J.ENPOL.2018.12.048

Edquist, C. (2004). Reflections on the systems of innovation approach. *Science and Public Policy*, *31*(6), 485-489. doi: 10.3152/147154304781779741

Edquist, C., & Johnson, B. J. (1997). Institutions and organizations in systems of innovation..

Enervalis. (2018a). *How energy trading between households through blockchain becomes reality in the Netherlands: Hoog Dalem 2.0.* Retrieved 2019-04-12, from `https://www.enervalis.com/2018/07/30/how-energy-trading-between-households-through-blockchain-becomes-reality-in-the-netherlands-hoog-dalem-2-0/`

Enervalis. (2018b). *World's first full smart energy community with Blockchain technology Enervalis.* Retrieved 2019-04-11, from `https://www.enervalis.com/2018/01/03/worlds-first-full-smart-energy-community-with-blockchain-technology/`

Engerati. (2018). *Lessons from peer-to-peer energy trading in the Netherlands.* Retrieved 2019-07-

08, from https://www.engerati.com/energy-retail/article/energy-trading/lessons-peer-peer-energy-trading-netherlands

Enserink, B., Hermans, L., Koppenjan, J., Bots, P., Kwakkel, J., & Thissen, W. (2010). *Policy analysis of multi-actor systems*. Eleven International Publishing.

ENTSO-E. (2015). *The Harmonised Electricity Market Role Model* (Tech. Rep.). Author. Retrieved from www.entsoe.eu

Fischer, W., Hake, J.-F., Kuckshinrichs, W., Schröder, T., & Venghaus, S. (2016). German energy policy and the way to sustainability: Five controversial issues in the debate on the energiewende. *Energy*, *115*, 1580 - 1591. (Sustainable Development of Energy, Water and Environment Systems) doi: https://doi.org/10.1016/j.energy.2016.05.069

Friedman, B., Kahn, P. H., Borning, A., & Huldtgren, A. (2013). Value sensitive design and information systems. In N. Doorn, D. Schuurbiers, I. van de Poel, & M. E. Gorman (Eds.), *Early engagement and new technologies: Opening up the laboratory* (pp. 55–95). Dordrecht: Springer Netherlands. doi: 10.1007/978-94-007-7844-3_4

Gautier, A., Jacqmin, J., & Poudou, J.-C. (2018). The prosumers and the grid. *Journal of Regulatory Economics*, *53*(1), 100–126.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6), 897 - 920. doi: https://doi.org/10.1016/j.respol.2004.01.015

Geels, F. W. (2018). Sustainability transitions. In *Companion to environmental studies* (Vol. 719, pp. 719–724). ROUTLEDGE in association with GSE Research.

Gemeente Eemnes. (2017). *Eemnes krijgt eerste slimme elektriciteitsnet ter wereld - Gemeente Eemnes.* Eemnes. Retrieved 2019-04-11, from https://www.eemnes.nl/Bestuur/Nieuws_en_bekendmakingen/Archief_nieuwsberichten/Archief_nieuwsberichten_2017/Eemnes_krijgt_eerste_slimme_elektriciteitsnet_ter_wereld

Giotitsas, C., Pazaitis, A., & Kostakis, V. (2015). A peer-to-peer approach to energy production. *Technology in Society*, *42*, 28–38. doi: https://doi.org/10.1016/j.techsoc.2015.02.002

Gissey, G. C., Dodds, P. E., & Radcliffe, J. (2018). Market and regulatory barriers to electrical energy storage innovation. *Renewable and Sustainable Energy Reviews*, *82*, 781 - 790. doi: https://doi.org/10.1016/j.rser.2017.09.079

Gkatzikis, L., Koutsopoulos, I., & Salonidis, T. (2013). The role of aggregators in smart grid demand response markets. *IEEE Journal on Selected Areas in Communications*, *31*(7), 1247-1257. doi: 10.1109/JSAC.2013.130708

Goodin, R. (1998). *The theory of institutional design*. Cambridge University Press.

Graafland, J. J. (2003). Distribution of Responsibility, Ability and Competition. *Journal of Business Ethics*, *45*(1/2), 133–147. Retrieved from http://link.springer.com/10.1023/A:1024188916195 doi: 10.1023/A:1024188916195

Grandell, L., Lehtilä, A., Kivinen, M., Koljonen, T., Kihlman, S., & Lauri, L. S. (2016). Role of critical metals in the future markets of clean energy technologies. *Renewable Energy*, *95*, 53 - 62. doi: https://doi.org/10.1016/j.renene.2016.03.102

GridFlex. (2018). *Privacy by Design designation for Gridflex.* Retrieved 2019-04-11, from https://gridflex.nl/privacy-by-design-predikaat-voor-gridflex/

Gridflex Energie. (n.d.). *Duurzamer dan duurzaam.* Retrieved from https://www.natuurenmilieuoverijssel.nl/friksbeheer/wp-content/uploads/2017/10/energievoorziening-in-de-toekomst-GridFlex-Heeten.pdf

Guerreiro, S., Batel, S., Lima, M. L., & Moreira, S. (2015). Making energy visible: sociopsychological aspects associated with the use of smart meters. *Energy Efficiency*, *8*(6), 1149–1167. doi: 10.1007/s12053-015-9344-4

Gui, E. M., & MacGill, I. (2018). Typology of future clean energy communities: An exploratory structure, opportunities, and challenges. *Energy Research & Social Science*, *35*, 94–107. Retrieved from https://www.sciencedirect.com/science/article/pii/S221462961730347X{#}bib0055 doi: 10.1016/J.ERSS.2017.10.019

Han, L., Morstyn, T., & McCulloch, M. (2019). Incentivizing prosumer coalitions with energy management using cooperative game theory. *IEEE Transactions on Power Systems*, *34*(1), 303-313. doi: 10.1109/TPWRS.2018.2858540

Heldeweg, M. A., Sanders, M., & Harmsen, M. (2015). Public-private or private-private energy partnerships? toward good energy governance in regional and local green gas projects. *Energy, Sustainability and Society*, *5*(1), 9. doi: 10.1186/s13705-015-0038-8

Huijben, J., & Verbong, G. (2013). Breakthrough without subsidies? pv business model experiments in the netherlands. *Energy Policy*, *56*, 362 - 370. doi: https://doi.org/10.1016/j.enpol.2012.12.073

Huss, W. R. (1988). A move toward scenario analysis. *International Journal of Forecasting*, *4*(3), 377 - 388. (Special Issue on: The Future of Forecasting) doi: https://doi.org/10.1016/0169-2070(88)90105-7

ICT. (2019). *GridFlex Heeten investigates feasibility of local energy market* (Tech. Rep.). Retrieved from https://ict.eu/wp-content/uploads/2018/10/ICT-GROUP_Casestudy-Energy-GFH_UK_Dig.pdf

Ingrams, A. (2019). Public values in the age of big data: A public information perspective. *Policy & Internet*, *11*(2), 128-148. doi: 10.1002/poi3.193

International Energy Agency. (2018). *Status of Power System Transformation Advanced Power Plant Flexibility* (Tech. Rep.). Retrieved from https://webstore.iea.org/download/direct/1041?fileName=Status_of_Power_System_Transformation_2018.pdf

International Renewable Energy Agency. (2018). *Renewable Power Generation Costs in 2017*. Abu Dhabi: International Renewable Energy Agency. Retrieved from www.irena.org

Jacobsen, H. K., & Schröder, S. T. (2012). Curtailment of renewable generation: Economic optimality and incentives. *Energy Policy*, *49*, 663 - 675. (Special Section: Fuel Poverty Comes of Age: Commemorating 21 Years of Research and Policy) doi: https://doi.org/10.1016/j.enpol.2012.07.004

Jacobsson, B., Pierre, J., & Sundström, G. (2015). Governing the embedded state. In (p. 1-26). doi: 10.1093/acprof:oso/9780199684168.003.0001

Jogunola, O., Ikpehai, A., Anoh, K., Adebisi, B., Hammoudeh, M., Son, S.-Y., & Harris, G. (2017). State-of-the-art and prospects for peer-to-peer transaction-based energy system. *Energies*, *10*(12). doi: 10.3390/en10122106

Jägemann, C., Hagspiel, S., & Lindenberger, D. (2013). *The economic inefficiency of grid parity: The case of german photovoltaics* (EWI Working Paper No. 13/19). Retrieved from http://hdl.handle.net/10419/92970

Jørgensen, T. B., & Bozeman, B. (2007). Public values: An inventory. *Administration & Society*, *39*(3), 354-381. doi: 10.1177/0095399707300703

Karakaya, E., & Sriwannawit, P. (2015). Barriers to the adoption of photovoltaic systems: The state of the art. *Renewable and Sustainable Energy Reviews*, *49*, 60 - 66. doi: https://doi.org/10.1016/j.rser.2015.04.058

Klaassen, E. (2016). *Demand response benefits from a power system perspective: methodologies and evaluation of field tests* (Doctoral dissertation, Technische Universiteit Eindhoven). Retrieved from https://research.tue.nl/en/publications/demand-response-benefits-from-a-power-system-perspective-methodol

Klaassen, E., & Van Der Laan, M. (2019). *USEF White Paper Energy and Flexibility Services for Citizens Energy Communities A solid foundation for smart energy futures*

(Tech. Rep.). Retrieved from https://www.usef.energy/app/uploads/2019/02/USEF-White-Paper-Energy-and-Flexibility-Services-for-Citizens-Energy-Communities-final-CM.pdf

Kloppenburg, S., & Boekelo, M. (2019). Digital platforms and the future of energy provisioning: Promises and perils for the next phase of the energy transition. *Energy Research & Social Science*, *49*, 68–73. doi: https://doi.org/10.1016/j.erss.2018.10.016

Kohler, T., Steghöfer, J., Busquets, D., & Pitt, J. (2014). The value of fairness: Trade-offs in repeated dynamic resource allocation. In *2014 ieee eighth international conference on self-adaptive and self-organizing systems* (p. 1-10). doi: 10.1109/SASO.2014.12

Koirala, B. P., Koliou, E., Friege, J., Hakvoort, R. A., & Herder, P. M. (2016). Energetic communities for community energy: A review of key issues and trends shaping integrated community energy systems. *Renewable and Sustainable Energy Reviews*, *56*, 722–744. doi: 10.1016/j.rser.2015.11.080

Kooij, H.-J., Oteman, M., Veenman, S., Sperling, K., Magnusson, D., Palm, J., & Hvelplund, F. (2018). Between grassroots and treetops: Community power and institutional dependence in the renewable energy sector in Denmark, Sweden and the Netherlands. *Energy Research Social Science*, *37*, 52–64. doi: 10.1016/J.ERSS.2017.09.019

Koppenjan, J., & Groenewegen, J. (2005). Institutional design for complex technological systems. *International Journal of Technology, Policy and Management*, *5*. doi: 10.1504/IJTPM.2005.008406

Kushnir, D., & Sandén, B. A. (2012). The time dimension and lithium resource constraints for electric vehicles. *Resources Policy*, *37*(1), 93 - 103. doi: https://doi.org/10.1016/j.resourpol.2011.11.003

Künneke, R., Mehos, D. C., Hillerbrand, R., & Hemmes, K. (2015). Understanding values embedded in offshore wind energy systems: Toward a purposeful institutional and technological design. *Environmental Science Policy*, *53*, 118 - 129. (Crafting or designing? Science and politics for purposeful institutional change in Social-Ecological Systems) doi: https://doi.org/10.1016/j.envsci.2015.06.013

Lammers, I., & Diestelmeier, L. (2017). Experimenting with Law and Governance for Decentralized Electricity Systems: Adjusting Regulation to Reality? *Sustainability*, *9*(2), 212. Retrieved from http://www.mdpi.com/2071-1050/9/2/212 doi: 10.3390/su9020212

Lampropoulos, I., van den Broek, M., van der Hoofd, E., Hommes, K., & van Sark, W. (2018). A system perspective to the deployment of flexibility through aggregator companies in the netherlands. *Energy Policy*, *118*, 534 - 551. doi: https://doi.org/10.1016/j.enpol.2018.03.073

Lavrijssen, S., & Parra, A. C. (2017). Radical Prosumer Innovations in the Electricity Sector and the Impact on Prosumer Regulation. *Sustainability*, *9*(7), 1–21. Retrieved from https://ideas.repec.org/a/gam/jsusta/v9y2017i7p1207-d104215.html

Leal-Arcas, R., Lesniewska, F., & Proedrou, F. (2018a). Prosumers as new energy actors. In M. Mpholo, D. Steuerwald, & T. Kukeera (Eds.), *Africa-eu renewable energy research and innovation symposium 2018 (reris 2018)* (pp. 139–151). Cham: Springer International Publishing.

Leal-Arcas, R., Lesniewska, F., & Proedrou, F. (2018b). Prosumers: New actors in eu energy security. In F. Amtenbrink, D. Prévost, & R. A. Wessel (Eds.), *Netherlands yearbook of international law 2017: Shifting forms and levels of cooperation in international economic law: Structural developments in trade, investment and financial regulation* (pp. 139–172). The Hague: T.M.C. Asser Press. doi: 10.1007/978-94-6265-243-9_5

Ligtvoet, A., van de Kaa, G., Fens, T., van Beers, C., Herder, P., & van den Hoven, J. (2015). Value sensitive design of complex product systems. In M. Janssen, M. A. Wimmer, & A. Deljoo (Eds.), *Policy practice and digital science: Integrating complex systems, social simulation* *and public administration in policy research* (pp. 157–176). Cham: Springer International Publishing. doi: 10.1007/978-3-319-12784-2_8

Ligtvoet, A., van de Kaa, G., Fens, T., van den Hoven, M. J., van Beers, C., & Herder, P. M. (2014). Stakeholder values and platform wars: smart meters in the nethrlands..

Lindgren, M., & Bandhold, H. (2003). *Scenario planning*. Springer.

Long, C., Wu, J., Zhang, C., Cheng, M., & Al-Wakeel, A. (2017). Feasibility of peer-to-peer energy trading in low voltage electrical distribution networks. *Energy Procedia*, *105*, 2227 - 2232. (8th International Conference on Applied Energy, ICAE2016, 8-11 October 2016, Beijing, China) doi: https://doi.org/10.1016/j.egypro.2017.03.632

Luthander, R., Widén, J., Nilsson, D., & Palm, J. (2015). Photovoltaic self-consumption in buildings: A review. *Applied Energy*, *142*, 80 - 94. doi: https://doi.org/10.1016/j.apenergy.2014.12.028

Manzoor, A. (2014). A look at efficiency in public administration: Past and future. *SAGE Open*, *4*(4), 2158244014564936. doi: 10.1177/2158244014564936

March, J., & Olsen, J. (2010). *Rediscovering institutions*. Free Press.

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955 - 967. (Special Section on Sustainability Transitions) doi: https://doi.org/10.1016/j.respol.2012.02.013

Martens, B., Mummert, U., Murrell, P., Seabright, P., & Ostrom, E. (2002). *The institutional economics of foreign aid*. Cambridge University Press.

Masson, G., Orlandi, S., Petrick, K., Cassagne, V., Ignacio Briano, J., Jesus Baez Morandi, M., ... Rickerson, W. (2014). Pv development as prosumers: The role and challenges associated to producing and self-consuming pv electricity..

McKenna, R. (2018). The double-edged sword of decentralized energy autonomy. *Energy Policy*, *113*, 747 - 750. doi: https://doi.org/10.1016/j.enpol.2017.11.033

Mees, H. L. P., Driessen, P. P. J., & Runhaar, H. A. C. (2014, 01). Legitimate adaptive flood risk governance beyond the dikes: the cases of hamburg, helsinki and rotterdam. *Regional Environmental Change*, *14*(2), 671–682. doi: 10.1007/s10113-013-0527-2

Mengelkamp, E., Gärttner, J., Rock, K., Kessler, S., Orsini, L., & Weinhardt, C. (2018). Designing microgrid energy markets: A case study: The Brooklyn Microgrid. *Applied Energy*, *210*, 870–880. doi: https://doi.org/10.1016/j.apenergy.2017.06.054

Milchram, C., de Kaa, G. V., Doorn, N., & Künneke, R. (2018). Moral Values as Factors for Social Acceptance of Smart Grid Technologies. *Sustainability*, *10*(8), 1-23.

Milchram, C., Hillerbrand, R., van de Kaa, G., Doorn, N., & Künneke, R. (2018). Energy justice and smart grid systems: Evidence from the netherlands and the united kingdom. *Applied Energy*, *229*, 1244 - 1259. doi: https://doi.org/10.1016/j.apenergy.2018.08.053

Ministry of Economic Affairs. (2016). *Energy Report Transition to sustainable energy* (Tech. Rep.).

Moraga, J. L., & Mulder, M. (2018). *Electrification of heating and transport: a scenario analysis for the Netherlands up to 2050* (Tech. Rep.). Groningen: Centre on Regulation in Europe (CERRE). Retrieved from `http://www.rug.nl/feb/`

Moreno, B., López, A. J., & García-Álvarez, M. T. (2012). The electricity prices in the european union. the role of renewable energies and regulatory electric market reforms. *Energy*, *48*(1), 307 - 313. (6th Dubrovnik Conference on Sustainable Development of Energy Water and Environmental Systems, SDEWES 2011) doi: https://doi.org/10.1016/j.energy.2012.06.059

Moreno, R., Street, A., Arroyo, J. M., & Mancarella, P. (2017). Planning low-carbon electricity systems under uncertainty considering operational flexibility and smart grid technologies. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *375*(2100), 20160305. doi: 10.1098/rsta.2016.0305

Morstyn, T., Farrell, N., Darby, S. J., & McCulloch, M. D. (2018). Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants. *Nature Energy*, *3*(2), 94–101. doi: 10.1038/s41560-017-0075-y

Mulder, M. (2017). *Energy transition and the electricity market: an exploration of a electrifying relationship* (Vol. 1). Groningen: Centre for Energy Economics Research, University of Groningen,.

Nabatchi, T. (2012). Putting the public back in public values research: Designing participation to identify and respond to values. *Public Administration Review*, *72*(5), 699-708. doi: 10.1111/j.1540-6210.2012.02544.x

Ongkiehong, O., & SenterNovem EOS. (2006). *Electricity grids: Description of the state under the Dutch energy research program EOS (Energie Onderzoek Strategie)* (Tech. Rep.). Retrieved from `https://www.rvo.nl/sites/default/files/bijlagen/StatusReportElectricitygridsEOS.pdf`

Painter, M., Burns, J. P., & Yee, W.-H. (2010). Explaining autonomy in public agencies: The case of hong kong. In P. Laegreid & K. Verhoest (Eds.), *Governance of public sector organizations: Proliferation, autonomy and performance* (pp. 111–132). London: Palgrave Macmillan UK. doi: 10.1057/9780230290600_6

Parag, Y., & Sovacool, B. K. (2016). Electricity market design for the prosumer era. *Nature Energy*, *1*(4), 16032. doi: 10.1038/nenergy.2016.32

Parrish, B., Gross, R., & Heptonstall, P. (2019). On demand: Can demand response live up to expectations in managing electricity systems? *Energy Research Social Science*, *51*, 107 - 118. doi: https://doi.org/10.1016/j.erss.2018.11.018

Pedersen, A. R., Sehested, K., & Sørensen, E. (2011). Emerging theoretical understanding of pluricentric coordination in public governance. *The American Review of Public Administration*, *41*(4), 375-394. doi: 10.1177/0275074010378159

Ponds, K. T., Arefi, A., Sayigh, A., & Ledwich, G. (2018). Aggregator of demand response for renewable integration and customer engagement: Strengths, weaknesses, opportunities, and threats. *Energies*, *11*(9). doi: 10.3390/en11092391

Powerpeers. (2019). *Powerpeers. Power to the people!* Retrieved 2019-04-12, from `https://www.powerpeers.nl/`

Rai, V., Reeves, D. C., & Margolis, R. (2016). Overcoming barriers and uncertainties in the adoption of residential solar pv. *Renewable Energy*, *89*, 498 - 505. doi: https://doi.org/10.1016/j.renene.2015.11.080

Rhodes, R., & Wanna, J. (2007). The limits to public value, or rescuing responsible government from the platonic guardians. *Australian Journal of Public Administration*, *66*(4), 406-421. doi: 10.1111/j.1467-8500.2007.00553.x

Rounsevell, M. D. A., & Metzger, M. J. (2010). Developing qualitative scenario storylines for environmental change assessment. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(4), 606–619. Retrieved from `http://doi.wiley.com/10.1002/wcc.63` doi: 10.1002/wcc.63

Ruotsalainen, J., Karjalainen, J., Child, M., & Heinonen, S. (2017). Culture, values, lifestyles, and power in energy futures: A critical peer-to-peer vision for renewable energy. *Energy Research Social Science*, *34*, 231 - 239. doi: https://doi.org/10.1016/j.erss.2017.08.001

Saboori, H., Mohammadi, M., & Taghe, R. (2011). Virtual power plant (vpp), definition, concept, components and types. In *2011 asia-pacific power and energy engineering conference* (p. 1-4). doi: 10.1109/APPEEC.2011.5749026

Schoemaker, P. J. (2004). Forecasting and scenario planning: the challenges of uncertainty and complexity.

Schwartz, P. (1991). *The Art of the Long View*. Doubleday/Currency. Retrieved from `https://books.google.nl/books?id=4vcOAQAAMAAJ`

Schwartz, S. (2013). Value priorities and behavior: Applying. In *The psychology of values: The ontario symposium* (Vol. 8).

SGTF-EG3. (2015). *Regulatory Recommendations for the Deployment of Flexibility* (Tech. Rep.). Retrieved from `https://ec.europa.eu/energy/sites/ener/files/documents/EG3Final-January2015.pdf`

Shaukat, N., Ali, S., Mehmood, C., Khan, B., Jawad, M., Farid, U., ... Majid, M. (2018). A survey on consumers empowerment, communication technologies, and renewable generation penetration within smart grid. *Renewable and Sustainable Energy Reviews*, *81*, 1453 - 1475. doi: https://doi.org/10.1016/j.rser.2017.05.208

Sheppard, B. H., & Lewicki, R. J. (1987). Toward general principles of managerial fairness. *Social Justice Research*, *1*(2), 161–176. doi: 10.1007/BF01048014

Sonnen Group. (2019). *sonnenCommunity.* Retrieved 2019-04-22, from `https://sonnengroup.com/sonnencommunity/`

Sorin, E., Bobo, L., & Pinson, P. (2019). Consensus-based approach to peer-to-peer electricity markets with product differentiation. *IEEE Transactions on Power Systems*, *34*(2), 994-1004. doi: 10.1109/TPWRS.2018.2872880

Sousa, T., Soares, T., Pinson, P., Moret, F., Baroche, T., & Sorin, E. (2019). Peer-to-peer and community-based markets: A comprehensive review. *Renewable and Sustainable Energy Reviews*, *104*, 367–378. doi: https://doi.org/10.1016/j.rser.2019.01.036

Spectral. (2017). *Jouliette at De Ceuvel.* Retrieved 2019-04-12, from `https://spectral.energy/news/jouliette-at-deceuvel/`

Spectral. (2018). *Projects.* Retrieved 2019-04-17, from `https://spectral.energy/projects/{#}groningen`

Stedin. (2018a). *Hoog Dalem 2.0: huishoudens verkopen energie aan buren.* Retrieved 2019-04-12, from `https://www.stedin.net/over-stedin/pers-en-media/persberichten/hoog-dalem-20-huishoudens-verkopen-energie-aan-buren`

Stedin. (2018b). *Hoog Dalem: Een all electric wijk en energie community'.* Retrieved 2019-04-12, from `https://www.stedin.net/over-stedin/projecten/hoog-dalem`

Stedin, & Energy21. (2018). *Layered Energy System (LES): Inclusive Enablement of Local Power* (Tech. Rep.). Retrieved 2019-04-13, from `https://www.stedin.net/over-stedin/~/media/files/stedin/projecten/layered-energy-system-white-paper.pdf`

Steenhuisen, B. (2009). *Competing public values: Coping strategies in heavily regulated utility industries* (Unpublished doctoral dissertation). Delft University of Technology.

Steenhuisen, B. (2010). Studying values in public policy: comparing five approaches. In *Irspm xiv: 14th annual conference of the international research society for public management, berne, switzerland, 7-9 april, 2010.*

Steenhuisen, B., Dicke, W., & de Bruijn, H. (2009). soft public values in jeopardy: Reflecting on the institutionally fragmented situation in utility sectors. *International Journal of Public Administration*, *32*(6), 491-507. doi: 10.1080/01900690902861753

Steg, L., Bolderdijk, J. W., Keizer, K., & Perlaviciute, G. (2014). An integrated framework for encouraging pro-environmental behaviour: The role of values, situational factors and goals. *Journal of Environmental Psychology*, *38*, 104 - 115. doi: https://doi.org/10.1016/j.jenvp.2014.01.002

Stewart, J. (2006). Value conflict and policy change. *Review of Policy Research*, *23*(1), 183-195. doi: 10.1111/j.1541-1338.2006.00192.x

Sung, B., & Park, S.-D. (2018). Who drives the transition to a renewable-energy economy? multi-actor perspective on social innovation. *Sustainability*, *10*(2). doi: 10.3390/su10020448

Taebi, B., Correljé, A., Cuppen, E., Dignum, M., & Pesch, U. (2014). Responsible innovation as an endorsement of public values: the need for interdisciplinary research. *Journal of Responsible*

Innovation, *1*(1), 118-124. doi: 10.1080/23299460.2014.882072
Taebi, B., & Kadak, A. C. (2010). Intergenerational considerations affecting the future of nuclear power: Equity as a framework for assessing fuel cycles. *Risk Analysis*, *30*(9), 1341-1362. doi: 10.1111/j.1539-6924.2010.01434.x
Tanna, V. (2018). *PowerToShare highlights, achievements, opportunities.* Retrieved 2019-04-12, from https://www.toblockchain.nl/toblockchain-powertoshare-highlights2017/
Tanrisever, F., Derinkuyu, K., & Jongen, G. (2015). Organization and functioning of liberalized electricity markets: An overview of the Dutch market. *Renewable and Sustainable Energy Reviews*, *51*, 1363–1374. Retrieved from https://www.sciencedirect.com/science/article/pii/S1364032115006668 doi: 10.1016/J.RSER.2015.07.019
Tennet. (n.d.). *Balancing responsibility.* Retrieved 2019-07-02, from https://www.tennet.eu/electricity-market/dutch-market/balancing-responsibility/
TenneT. (2019a). *Metering companies (NL).* Retrieved 2019-08-02, from https://www.tennet.eu/our-key-tasks/energy-industry/metering-companies-nl/
TenneT. (2019b). *TenneT: continuing with Blockchain after successful pilots.* Retrieved 2019-04-14, from https://www.tennet.eu/news/detail/tennet-continuing-with-blockchain-after-successful-pilots/
The Green Village. (2018). *TOBLOCKCHAIN.* Retrieved 2019-04-12, from https://www.thegreenvillage.org/projects/toblockchain
ToBlockchain. (2018). *A live energy blockchain demonstration.* Retrieved 2019-04-12, from https://www.toblockchain.nl/a-live-energy-blockchain-demonstration/
Tushar, W., Saha, T. K., Yuen, C., Liddell, P., Bean, R., & Poor, H. V. (2018). Peer-to-Peer Energy Trading with Sustainable User Participation: A Game Theoretic Approach. Retrieved from http://arxiv.org/abs/1809.11034
Ueckerdt, F., Brecha, R., & Luderer, G. (2015). Analyzing major challenges of wind and solar variability in power systems. *Renewable Energy*, *81*, 1–10. doi: 10.1016/J.RENENE.2015.03.002
Universal Smart Energy Framework. (2015). *USEF: THE FRAMEWORK EXPLAINED* (Tech. Rep.). USEF.
van de Poel, I. (2011). The Relation Between Forward-Looking and Backward-Looking Responsibility. In N. A. Vincent, I. van de Poel, & J. van den Hoven (Eds.), *Moral responsibility: Beyond free will and determinism* (pp. 37–52). Dordrecht: Springer Netherlands. doi: 10.1007/978-94-007-1878-4_3
van de Poel, I., & Royakkers, L. (2011). *Ethics, technology, and engineering: An introduction*. Wiley.
van der Heijden, K. (2011). *Scenarios: The art of strategic conversation*. Wiley.
van der Schoor, T., & Scholtens, B. (2015). Power to the people: Local community initiatives and the transition to sustainable energy. *Renewable and Sustainable Energy Reviews*, *43*, 666 - 675. doi: https://doi.org/10.1016/j.rser.2014.10.089
van der Stelt, S., AlSkaif, T., & van Sark, W. (2018). Techno-economic analysis of household and community energy storage for residential prosumers with smart appliances. *Applied Energy*, *209*, 266 - 276. doi: https://doi.org/10.1016/j.apenergy.2017.10.096
van Gestel, N., Koppenjan, J., Schrijver, I., van de Ven, A., & Veeneman, W. (2008). Managing public values in public-private networks: A comparative study of innovative public infrastructure projects. *Public Money Management*, *28*(3), 139-145. doi: 10.1111/j.1467-9302.2008.00635.x
van Notten, P. W. (2006). Scenario development : a typology of approaches..
Van Notten, P. W., Rotmans, J., Van Asselt, M. B., & Rothman, D. S. (2003). An updated scenario

typology. *Futures*, *35*(5), 423–443.

van Thiel, S., & Yesilkagit, K. (2014). Does task matter? the effect of task on the establishment, autonomy and control of semi-autonomous agencies. *International Review of Administrative Sciences*, *80*(2), 318-340. doi: 10.1177/0020852313514524

van Zalk, J., & Behrens, P. (2018). The spatial extent of renewable and non-renewable power generation: A review and meta-analysis of power densities and their application in the u.s. *Energy Policy*, *123*, 83 - 91. doi: https://doi.org/10.1016/j.enpol.2018.08.023

Verhoest, K., Roness, P., Verschuere, B., Rubecksen, K., & McCarthaigh, M. (2010). *Autonomy and control of state agencies: comparing states and agencies*. Palgrave Macmillan.

Verkade, N., & Höffken, J. (2018). The design and development of domestic smart grid interventions: Insights from the netherlands. *Journal of Cleaner Production*, *202*, 799 - 805. doi: https://doi.org/10.1016/j.jclepro.2018.08.185

von Meier, A. (2006). *Electric power systems: A conceptual introduction*. Wiley.

von Wirth, T., Gislason, L., & Seidl, R. (2018). Distributed energy systems on a neighborhood scale: Reviewing drivers of and barriers to social acceptance. *Renewable and Sustainable Energy Reviews*, *82*, 2618 - 2628. doi: https://doi.org/10.1016/j.rser.2017.09.086

Voulis, N. (2019). *Harnessing heterogeneity: Understanding urban demand to support the energy transition* (Unpublished doctoral dissertation). Delft University of Technology.

Vu Van, T., Norton, M., Ivanov, C., Delimar, M., Hatziargyriou, N., Stromsather, J., ... Panciatici, P. (2015). Organic growth: Toward a holistic approach to european research and innovation. *IEEE Power and Energy Magazine*, *13*(1), 30-37. doi: 10.1109/MPE.2014.2363525

Vuorinen, L., & Martinsuo, M. (2019). Value-oriented stakeholder influence on infrastructure projects. *International Journal of Project Management*, *37*(5), 750 - 766. (Special Issue: Delivering Value in Projects and Project-Based Business) doi: https://doi.org/10.1016/j.ijproman.2018.10.003

Watson, J., & Devine-Wright, P. (2011). Centralization, decentralization and the scales in between: what role might they play in the uk energy system? In T. Jamasb & M. G. Pollitt (Eds.), *The future of electricity demand: Customers, citizens and loads* (p. 280297). Cambridge University Press. doi: 10.1017/CBO9780511996191.017

Williams, I., & Shearer, H. (2011). Appraising public value: Past, present and futures. *Public Administration*, *89*(4), 1367-1384. doi: 10.1111/j.1467-9299.2011.01942.x

Yaqoot, M., Diwan, P., & Kandpal, T. C. (2016). Review of barriers to the dissemination of decentralized renewable energy systems. *Renewable and Sustainable Energy Reviews*, *58*, 477 - 490. doi: https://doi.org/10.1016/j.rser.2015.12.224

Yousif, M., Ai, Q., Wattoo, W. A., Jiang, Z., Hao, R., & Gao, Y. (2019). Least cost combinations of solar power, wind power, and energy storage system for powering large-scale grid. *Journal of Power Sources*, *412*, 710 - 716. doi: https://doi.org/10.1016/j.jpowsour.2018.11.084

Zhang, C. (2017). *Peer-to-peer energy trading in electrical distribution networks* (Doctoral dissertation, Cardiff University). Retrieved from `http://orca.cf.ac.uk/109074/`

Zhang, C., Wu, J., Long, C., & Cheng, M. (2017). Review of Existing Peer-to-Peer Energy Trading Projects. *Energy Procedia*, *105*, 2563–2568. doi: 10.1016/J.EGYPRO.2017.03.737

Zhang, C., Wu, J., Zhou, Y., Cheng, M., & Long, C. (2018). Peer-to-Peer energy trading in a Microgrid. *Applied Energy*, *220*, 1–12. doi: 10.1016/j.apenergy.2018.03.010

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A. Assumptions and Limitations

This chapter provides assumptions used for the thesis. In order to provide clarity, assumptions are listed according to the corresponding chapter.

A.1 Theoretical Framework

There are three primary key concepts used in the theoretical framework: (1) the distribution of tasks, (2) public values, and (3) safeguard public value. The following section will list assumptions made for those key concepts.

A.1.1 Distribution of Tasks

1. As the notion of distribution of tasks in the energy sector does not have a definitive definition, this concept is derived from the field study in public administration and public policy.
2. The identification of tasks is based on the conceptualisation of public values.
3. The distribution of tasks is expected to safeguard public values.
4. The distribution of tasks based on actor's role(s) and resource(s) is expected to achieve effectiveness, efficiency, and equity.

A.1.2 Public Values

1. Public values are limited to the current values that are embedded into the power system based on three primary layers, physical, information, and commercial layers.
2. The conceptualisation of public values is based on literature and is able to represent the conceptualisation of public values for all actors in the energy systems.

A.1.3 Safeguard public values

1. The distribution of tasks safeguards public values when actors are able to successfully discharge their assigned task(s) in order to protect or realise public values.
2. Accordingly, the distribution of tasks is unable to safeguard public values if actors face value conflicts. Third, value conflicts occur when: (1) the realisation of one value may hinder the

realisation of other value or (2) competing tasks associated with a certain public value.

3. Government's involvement through interventions is considered the only option to safeguard public values.

A.2 Scenario of Decentralised Energy Systems

1. General assumptions: the primary drivers are more control oversupply, sustainability, and self-sufficiency.
2. The government removes barriers such as the green tax and eliminate net-metering scheme to stimulate technological innovation in renewable technologies.
3. The value of economies of scale is relative to energy price.
4. Prosumers
   (a) Prosumers do not require any supplier license in order to conduct direct energy trading. Instead, by entering contractual agreements with the ISPs, the ISPs provide legal requirements for such a license.
   (b) Each participant in the Plasma scenario owns solar panels, energy storage, and home automation (domotica).
   (c) Prosumers are assumed a role as producer because they feed in electricity to the grids and receive remuneration from their commercial energy products (excess electricity or storage).
   (d) Prosumers' assets are assumed to be homogeneous.
   (e) Socio-economic characteristics of the prosumers are not taken into account for the development of scenario.
5. Independent Service Providers (ISPs)
   (a) ISPs are independent companies which are unrelated to the current incumbent actors in the energy system. The emergence of ISPs replace the need for conventional energy suppliers. This assumption is made because current literature recognises them as service providers (Stedin & Energy21, 2018). However, it is possible that existing actors may switch to ISPs. For the sake of clarity, the built scenario is based on ISPs and further discussion is provided in order to identify possible changes in actors' arrangement.
   (b) It is assumed that the primary assets of ISPs are technological innovations, infrastructures, and knowledge.
   (c) ISPs have contractual agreements with BRPs for balance responsibility because of limited financial resources.
   (d) ISPs do not only offer energy trading services by means of energy sharing platforms but also provide auxiliary services such as technological infrastructure (energy storage and smart devices) to their members. This additional services allow ISPs to perform balancing within their network reducing imbalance cost imposed by network operators.
6. Distribution System Operators (DSOs)
   (a) DSOs act as the system operator for the grid because they are expected to manage fluctuations in the distribution network caused by the integration of decentralised energy generation.
   (b) As the role will overlap with the TSO, this research only focuses on the role of DSOs as the system operator. In this scenario, DSOs are assumed to have resources such as flexibility from market participants connected to the distribution networks.
   (c) Additional interactions between ISPs and DSOs are expected in order to ensure that the orders within the platforms are within the technical specification of the distribution networks. Furthermore,
7. Balance Responsible Parties (BRPs)
   (a) It is assumed that BRPs take the role of balance responsibility party for the ISPs and

their members.

8. Centralised Energy Producers
    (a) Centralised energy producers are involved as part of BRPs' portfolio.

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B. Public Values Identification

In this appendix, a literature review on public values that are relevant to this research are presented. The purpose of this literature review is to provide an overview of public values found in the literature and synthesising which public values are considered essential for the analysis.

B.1 Data collection

The identification of public values in the Dutch energy sector is essential to the research for the analysis of potential institutional change caused by the integration of decentralised energy generation. Additionally, these values serve as a preliminary list of values used for the qualitative content analysis for the subsequent analysis. In order to establish the conceptual understanding on values, a literature review was conducted by utilising online databases such as Web of Science, Science Direct, GoogleScholar, and Scopus. The following keywords were used for the preliminary literature search via :

Table B.1: Keywords Used for Values Identification

Keywords	# of Results
TITLE-ABS-KEY (public AND values AND netherlands) AND (LIMIT-TO (SUBJAREA , "ENER"))	32
TITLE-ABS-KEY (public AND values AND dutch) AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016)) AND (LIMIT-TO (SUBJAREA , "ENER"))	7
(KEY (public AND values)) AND (netherlands) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015)) AND (LIMIT-TO (SUBJAREA , "ENER"))	18

B.2 Public Values Identified

In the collected databases, content analysis was conducted to filter articles that were relevant to the study based on the article's title and abstract. Here only recent articles were selected ranging from 2015 to 2020. Additionally, snowballing strategy was also used in order to extent the preliminary search result. In order to avoid repetitive and redundancy, some values were merged based on the provided value conceptualisation. As a result, a list of 19 unique values were generated in the context of the Dutch energy sector. Table B.2 and B.3 provide the conceptualisation of each value as well as its reference(s).

Table B.2: Substantive Values Identified from Literature Review

Value	Conceptualisation	Reference(s)
Aesthetic	Beauty of the landscape. Can be intrepreted as changes in landscape due to specific projects.	Dignum et al. (2016)
Economic development/profitability	Refers to a system that develops in a way it can generate profits in competitive markets.	Ligtvoet et al. (2015)
Environment friendliness/sustainability	According to Taebi and Kadak (2010), environment friendliness refers to Preserving the status of nature leaving it no worse than we found it (p. 1345). This value can also be interpreted based on the non-anthropocentric mode which means that the environment has an intrinsic value; take into account possible environmental effects of technical designs.	Demski et al. (2015); Dignum et al. (2016); Friedman et al. (2013); Ligtvoet et al. (2015)
Heatlh and Safety	Refers to energy system that is not harming people and their health including their state of complete physical, mental, and social well-being.	Dignum et al. (2016); Ligtvoet et al. (2015)
International stability	Stability in relation to energy supply including concerns about import dependency and energy reserves	Demski et al. (2015); Dignum et al. (2016); M. Edens (2017)
Ownership and property	Refers to a system that accommodates the ownership of an object or of information. Additionally the system allows its owner to use it, manage it, bequeath it.	Friedman et al. (2013)
Reliability	Refers to the ability of a system to deliver its function over a period of time without malfunctioning including reduction/prevention/avoidance of failure, unintended, consequences, and interference in the desired outcomes; a system that minimises the risk of failure	Demski et al. (2015); M. Edens (2017); M. G. Edens and Lavrijssen (2019); Künneke et al. (2015); Ligtvoet et al. (2015)
Resource durability	Avalaibility of energy resources for future generation including conservation of existing fossil fuels and the developments of renewable technologies	(Demski et al., 2015; Dignum et al., 2016)
Welfare	Affordability and economic viability of the decision (not) to pursue specific project(s).	Demski et al. (2015); Dignum et al. (2016); Friedman et al. (2013); Ligtvoet et al. (2015)

Table B.3: Procedural Values Identified from Literature Review

Value	Conceptualisation	Reference(s)
Accountability	A sound and legal arrangement that correspond to institutional framework. It can also mean a system that allows tracing the activities of individuals and institutions.	Dignum et al. (2016); Friedman et al. (2013); Ligtvoet et al. (2015)
Procedural justice	Fairness in the process of decision-making by giving all relevant stakeholders same opportunity to participate in the process.	Demski et al. (2015); Dignum et al. (2016)
Distributive justice	Fair and equitable distribution and allocation of outcomes including benefits, costs, external or internal effects across individuals or groups.	Demski et al. (2015); Dignum et al. (2016); Friedman et al. (2013); Künneke et al. (2015); Ligtvoet et al. (2015)
Legitimacy	Refers to a system that is developed on a sound legal basis and having broad support.	Dignum et al. (2016); Ligtvoet et al. (2015)
Informed consent	Refers to gathering peoples agreement, encompassing criteria of disclosure and comprehension (for informed) and agreement (for "consent")	Friedman et al. (2013); Ligtvoet et al. (2015)
Privacy	Refers to a system that allows people to determine which personal information can be collected, shared, used, and stored.	Friedman et al. (2013)
Autonomy	Refers to a system which enables its users to obtain their own goals based on their own decisions and choices	(Demski et al., 2015; Friedman et al., 2013; Ligtvoet et al., 2015)
Transparency	Transparency relates to the possibility of a multitude actors in the electricity system to anticipate possible changes in governance.	Ligtvoet et al. (2015)
Universal usability	Refers to a system that provides opportunity for everyone in the society to be successful users.	Friedman et al. (2013); Ligtvoet et al. (2015)
Trust	According to Friedman et al. (2013), trust refers to "expectations that exist between people who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal" (p. 58). Belief in other actors' reliability in their interactions with each other.	Friedman et al. (2013); Ligtvoet et al. (2015)

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C. Scenario Development and Trend Analysis

As mentioned in Chapter 3, trends towards decentralised energy systems are identified by the use of literature review from both scientific and grey literature. The following chapter provides the documentation of the analysis, followed by a synthesising section based on the findings.

Section C.1 provides the list of documents used for identifying trends and developments. Section C.2 presents current decentralised projects in the Netherlands. This information serves as the basis for identifying trends. Section C.3 presents an overview of the current trends in decentralised energy systems.

C.1 Data Collection

Table C.1 and Table C.2 provide lists of references used to identify trends and developments in the Dutch energy sector.

Table C.1: Grey Literature

Year	Author	Title	Type
2015	USEF	USEF: THE FRAMEWORK EXPLAINED	Tech Report
2016	Ministry of Economic Affairs	Energy Report Transition to sustainable energy	
2017	Gemeente Eemnes	Eemnes krijgt eerste slimme elektriciteitsnet ter wereld - Gemeente Eemnes	News
2017	ECN	The supply of flexibility for the power system in the Netherlands: Report of phase 2 of the FLEXNET project	Tech Report
2018	Bax & Company	Codeveloping the first large-scale peer-to-peer energy trading market in NL	News
2018	Stedin, & Energy21	Layered Energy System (LES): Inclusive Enablement of Local Power	Tech Report
2018	Moraga, J. L., & Mulder, M.	Electrification of heating and transport: a scenario analysis for the Netherlands up to 2050	Tech Report

Year	Author	Title	Type
2019	ICT	GridFlex Heeten investigates feasibility of local energy market	Tech Report
2019	Powerpeers	Powerpeers. Power to the people!	Website

Table C.2: Scientific Literature

Year	Author	Title	Type
2013	Jägemann, C., Hagspiel, S., & Lindenberger, D	The economic inefficiency of grid parity: The case of german photovoltaics	Scientific Article
2014	Bayram, I. S., Shakir, M. Z., Abdallah, M., & Qaraqe, K.	A survey on energy trading in smart grid	Scientific Article
2015	Karakaya, E., & Sriwannawit, P.	Barriers to the adoption of photovoltaic systems: The state of the art	Scientific Article
2015	van der Schoor, T., & Scholtens, B.	Power to the people: Local community initiatives and the transition to sustainable energy	Scientific Article
2016	Butenko, A	Sharing Energy: Dealing with Regulatory Disconnect in Dutch Energy Law	Scientific Article
2016	Bohnsack, R., Pinkse, J., & Waelpoel, A.	The institutional evolution process of the global solar industry: The role of public and private actors in creating institutional shifts	Scientific Article
2016	Grandell, L., Lehtilä, A., Kivinen, M., Koljonen, T., Kihlman, S., & Lauri, L. S.	Role of critical metals in the future markets of clean energy technologies	Scientific Article
2016	Klaassen, E.	Demand response benefits from a power system perspective: methodologies and evaluation of field tests	Doctoral dissertation
2016	Koirala, B. P., Koliou, E., Friege, J., Hakvoort, R. A., & Herder, P. M.	Energetic communities for community energy: A review of key issues and trends shaping integrated community energy systems	Scientific Article
2016	Parag, Y., & Sovacool, B. K.	Electricity market design for the prosumer era	Scientific Article
2016	Yaqoot, M., Diwan, P., & Kandpal, T. C.	Review of barriers to the dissemination of decentralised renewable energy systems	Scientific Article
2017	Moreno, R., Street, A., Arroyo, J. M., & Mancarella, P.	Planning low-carbon electricity systems under uncertainty considering operational flexibility and smart grid technologies	Scientific Article
2018	McKenna, R.	The double-edged sword of decentralised energy autonomy	Scientific Article
2018	Proka, A., Hisschemöller, M., & Loorbach, D.	Transition without conflict? renewable energy initiatives in the dutch energy transition	Scientific Article
2018	Rommel, J., Radtke, J., von Jorck, G., Mey, F., & Özgür Yildiz.	Community renewable energy at a crossroads: A think piece on degrowth, technology, and the democratisation of the german energy system	Scientific Article
2019	Kloppenburg, S., & Boekelo, M.	Digital platforms and the future of energy provisioning: Promises and perils for the next phase of the energy transition	Scientific Article
2019	Sousa, T., Soares, T., Pinson, P., Moret, F., Baroche, T., & Sorin, E.	Peer-to-peer and community based markets: A comprehensive review	Scientific Article
2013	Gkatzikis, L., Koutsopoulos, I., & Salonidis, T.	The role of aggregators in smart grid demand response markets	Scientific Article

Year	Author	Title	Type
2017	Jogunola, O., Ikpehai, A., Anoh, K., Adebisi, B., Hammoudeh, M., Son, S.-Y., & Harris, G.	Stateof-the-art and prospects for peer-to-peer transaction-based energy system	Scientific Article
2017	Long, C., Wu, J., Zhang, C., Cheng, M., & Al-Wakeel, A.	Feasibility of peer-to-peer energy trading in low voltage electrical distribution networks	Scientific Article
2018	Mengelkamp, E., Gärttner, J., Rock, K., Kessler, S., Orsini, L., & Weinhardt, C.	Designing microgrid energy markets: A case study: The Brooklyn Microgrid	Scientific Article
2018	Morstyn, T., Farrell, N., Darby, S. J., & McCulloch, M. D.	Using peer-to-peer energy-trading platforms to incentivise prosumers to form federated power plants	Scientific Article

C.2 Developments of Decentralised Energy Projects in the Netherlands

The inventory of potential actors involved in the application is based on the current institutional arrangements in the Netherlands as well as possible new actors that will emerge with the application of decentralised energy systems. To identify those actors, an overview of current pilot projects in the Netherlands is presented, followed by the inventory of other actors that may have interests in the application of decentralised energy systems.

C.2.1 Overview of decentralised energy projects in the Netherlands

Several pilot projects on decentralised energy systems have been carried out in recent years; some are still ongoing and others have already ended. Some of them focus on business case and technologies to enable local decentralised energy systems; others focus *on the local control and ICT systems for Microgrids*. The following sections explain the objectives as well as actors involved in the development of each pilot project.

The Eemnes Project, Netherlands

Unlike any other decentralised energy projects, this project is developed to create a decentralised energy systems market between households, local businesses, farmers, and public buildings in Eemnes, the Netherlands. Therefore, it aims to gradually scale up the pilot project to a maximum of 4000 participants. An exemption was granted by the Rijksdienst voor Ondernemend Nederland from the Electricity Act 1998 to the energy cooperative Eemnes Energie for up to 10 years to enable local energy trading in which households and small to medium-sized companies are able to trade electricity at prices determined by the local market or trade it on wider markets.

The combination of virtual currency based on blockchain technology and the latest generation of smart meters enables the implementation of decentralised energy systems. This project utilises blockchain technology to manage the database used for trading as well as the settlement of each transaction. This technology facilitates a decentralised database to warrant trust in the trading system. Consequently, it improves the transparency of the transactions in the P2P network, creating a faster and more open energy trading between peers. As such, this project promises to deliver affordable and sustainable energy, improve energy efficiency, and create shared value between communities.

This consortium consists of multiple actors from developers to the municipality. Enervalis provides technical support to predict electricity consumption and production, allowing a cost-effective green energy society. The municipality of Eemnes has focused on sustainable energy policy for the past eight years. Eemnes Energie, the province of Utrecht, the national government, and the European Union. Together, they strive to tackle the flaws of energy usage today while stimulating collaboration across the Netherlands. A second location for similar initiative is planned in Amersfoort (Bax & Company, 2018; Chapman, 2018; Enervalis, 2018b; Gemeente Eemnes, 2017).

Gridflex Heeten

The Gridflex Heeten is a local energy initiative in Heeten (Overijssel) to investigate the possibilities of zero-carbon homes by utilising solar PVs and home-based battery storage system. The objective of this project is to develop technology and "off the grid" business cases that are scalable and applicable to the future energy systems. The residents of this community are known for their active involvement in the energy transition; for example, they have collectively invested in solar panels through Buurkracht initiative. Therefore, companies such as Enexis and ICT Group recognise the potential of "off the grid" trial in the community.

There are several technological innovations used in the project such as sea salt batteries, IoT platform (energyNXT), and Energy Management System (EMS). A sea salt battery is cutting-edge technology in the battery storage system, developed by a Dutch firm Dr. Ten BV. This battery consists of minerals, carbon, and salt extracted from natural sources instead of lithium or lead-acid. The EnergyNXT platform involved in data processing activities, for example, households' production and consumption as well as monitor battery storage and redistribution of excess electricity among neighbourhoods. Meanwhile, the EMS is a mobile application for the residents that enables real-time monitoring of households' energy consumption.

This project emphasises the involvement of the community to be self-sufficient. The excess energy is no longer distributed back to the grid, but it will be redistributed to the neighbours who require extra power. Consequently, the community has control over electricity and will profit from local energy trading. A total of 48 homes are involved in the project with more than 700 solar panels of locally sustainable energy production. These homes are currently connected to a single transformer house. Other than the community itself, there are a few numbers of stakeholders involved in the project such as ICT Group, Enexis, University of Twente, Enpuls, Endona, Buurkracht, and Dr Ten (Dr Ten BV, n.d.; GridFlex, 2018; Gridflex Energie, n.d.; ICT, 2019).

Hoog Dalem

Hoog Dalem, Gorinchem is known as the only all-electric district in the Netherlands after a successful implementation of a new energy system in which houses are no longer connected to the gas mains. More than 40 households participated in the first trial project for maximising the use of self-generated energy via energy storage at home or in the neighbourhood. For this phase, the Universal Smart Energy Framework (USEF) method was used to send a demand for energy supply.

A new phase of pilot projects, "Hoog Dalem 2.0", is planned to enable local energy trading where a total of 14 households can produce and distribute energy to each other by utilising blockchain technology. For this phase, Stedin plans to implement Layered Energy System (LES) which was developed in collaboration with Energy21 (Stedin & Energy21, 2018). To conceptualise such setting, various parties are involved in the pilot project. As a grid operator, Stedin coordinates supply and demand for energy in order to reduce the load on the energy network. ABB supplies the necessary equipment for the local energy market. EWF Blockchain will record all transactions between households. Meanwhile, Enervalis provides a smart operating system for the residents as well as enables the Blockchain link and creates the transactions (Enervalis, 2018a; Stedin, 2018a, 2018b).

Jouliette at De Ceuvel

Jouliette at De Ceuvel is the pioneer of blockchain-based energy trading in the Netherlands. This project is located at a local community named De Ceuvel in Amsterdam, where the residents can trade energy through a local energy system managed by blockchain technology. Meanwhile, Jouliette represents a blockchain-based virtual currency to empower residents in managing and sharing their locally produced energy. As such, this project aims to explore the capabilities of blockchain technology to support the transition towards a more decentralised, robust, and transparent economy, supported by 100% renewable energy generation.

The community at De Ceuvel owns a private smart-grid which enables the residents to exchange energy independently without any intermediaries such as energy suppliers avoiding current energy market barriers. Further, Jouliette is expected to create greater social values such as facilitating a local time-banking system and integrating intra-community services. Accordingly, the technological structures of Jouliette at De Ceuvel may potentially create new connections between individuals, promote local control in the energy systems, and establish community-led energy systems.

The Jouliette platform is developed by Spectral, in collaboration with Alliander. Besides the decentralised energy systems system, this platform offers multiple services such as real-time electricity map, interactive data visualisation, and forecasting algorithm, which allow users to track their energy production and consumption in real-time (Spectral, 2017).

Powerpeers

Powerpeers is a community-based P2P platform that is built on a sharing economy concept which allows consumers to choose prosumers they wish to buy the electricity from. Both prosumers and consumers are able to track their energy production and consumption in near real-time, including from or whom they are trading electricity with. Additionally, when the electricity demand exceeds the electricity supply, Powerpeers will meet the demand by utilising other sustainable sources such as wind energy, this information is visible on the Powerpeers' energy dashboard. Powerpeers runs its system by using existing infrastructure and smart meter data and develops its P2P energy exchange based on blockchain technology. Powerpeers is a subsidiary of Vattenfall, a Dutch energy company (Kloppenburg & Boekelo, 2019; Powerpeers, 2019).

PowerToShare at The Green Village

PowerToShare by ToBlockchain is a blockchain-based P2P energy platform that includes energy source identification (e.g. solar, wind or bio-CHP), transactions' settlements, and balancing of the grid. A pilot project is conducted at the Green Village, TU Delft in collaboration with Engie (The Green Village, 2018; ToBlockchain, 2018). ToBlockchain is also involved in the development of a zero-carbon community in Groningen by using PowerToShare. This project is in collaboration with the N.V. Nederlandse Gasunie (utility infrastructure company) and DNV GL (Tanna, 2018).

Groningen Municipality projects

The City of Groningen has the vision to be energy neutral by 2025. To achieve this goal, the local government is working on the Energie delen met je buren (Sharing energy with your neighbours) project. Two phases are planned. The first phase will focus on households in the Reitdiep neighbourhood, whereas the second phase will scale up with another neighbourhood, Selwerd, participating in the project. The smart meter for each participant will be connected to physical hardware developed by Spectral in order to write data to the blockchain. Thus allowing each participant will be able to track their energy production and consumption in near real-time (Spectral, 2018).

C.2.2 Other Actors in Decentralised Energy Systems

Authority for Consumers and Markets (ACM)

ACM oversees competition in the energy market and to ensure enforcement of the Electricity and Gas law. In the context of decentralised energy systems, article 95a of the Elektriciteitswet 1998 states that a prosumer does not require to obtain a suppliers license to consume and produce their own energy. However, a suppliers license from the ACM is required if prosumers wish to supply energy to small or medium consumers (Butenko, 2016). As such, the application of decentralised energy systems may be of interest to ACM.

Tennet

Tennet is the responsible party for the transmission system, and the company holds a monopoly position in the Netherlands, which is regulated by law. Consequently, one primary task for Tennet is balancing the electricity grid by matching supply and demand on the grid. Therefore, Tennet requires all parties connected to the grids to be "balance responsible". Balance responsibility means that each party connected to the grid has a responsibility to inform the grid administrators of their planned electricity production, consumption, and transport needs. They must follow the submitted planned documents, and if they do not comply, they will need to settle the imbalance fees (Tennet, n.d.). Tennet has been involved in a few pilot projects to balance the high-voltage grid via electric vehicle cars and home batteries and to prevent congestion on the grid. Therefore, the emergence of decentralised energy systems along with its battery system, may contribute to balancing the grids (TenneT, 2019b).

Aggregator

An aggregator is relatively a new actor in the energy system and offers services to manage demand response pattern in the energy system. For instance, an aggregator can offer incentives to their large consumers to shift their operations during off-peak hours resulting in flexible grid management. Along with Tennet, aggregators such as ENGIE, Escozon & Energie Samen, Scholt Energy & Enervalis and Vandebron will involve in the upcoming projects to provide flexibility to the power system via various types of assets (e.g. home or centralised energy storage) (TenneT, 2019b).

Wholesale traders

Wholesale traders can supply energy demand for local P2P network by buying energy at a wholesale level and selling it in small "slices" to local energy markets. Further, these actors can also buy excess energy or flexibility at local levels.

Based on the aforementioned sections, Table C.3 provides a summary of the actors in the application of decentralised energy systems.

Table C.3: Summary of Actors in the Application of decentralised energy systems

Name of project	Actor	Description and interests
All	The national government	Grants exemptions for energy projects from the Electricity Act 1998. Encourage sustainable energy growth while safeguarding public values.
The Eemnes Project	Local community in Eemnes	Partner, producers and consumers of electricity. Optimise the energy production and consumption of sustainable energy.
	Enervalis	Technical provider. Enervalis provides software used for decentralised energy systems.
	The municipality of Eemnes	The municipality of Eemnes has power and financial means to develop and implement local policy on the energy transition.
	Eemnes Energie	A local energy cooperative located in Eemnes to coordinate collective renewable energy generation.
Gridflex Heeten	Local community in Heeten (Overijssel)	Partner, producers and consumers of electricity. Become self-sufficient energy community by utilising 100% renewable energy sources.
	Enexis B.V.	Researches the consequences of decentralised, sustainable energy generation, and the use of local storage to minimise fluctuation on the grid.

Name of project	Actor	Description and interests
	ICT Group	Partner, ICT Group provides technological solutions for decentralised energy systems such as an online platform.
	Dr. Ten B.V.	Partner, Dr. Ten B.V. provides technical knowledge in sustainable storage system made from sea salt. Proof of concept for sea salt battery storage.
	Energie Cooperatie Endona U.A.	Project manager and the owner of the project's exemption. Endona is a local energy cooperative to generate local and sustainable energy for residents and businesses.
	Enpuls B.V.	Enpuls is a part of Enexis NV. The core activities of Enpuls include measuring and analysing energy consumption, advising on energy infrastructure and savings, renting out technical assets and designing, and managing and maintaining (sustainable) energy facilities.
	Universiteit Twente	Partner for research and development in the field of energy management algorithms in local distribution grids.
Hoog Dalem	Local community at Hoog Dalem	Partner, producers and consumers of electricity. Optimise renewable energy production and consumption.
	Stedin	Stedin is responsible for operating low and medium voltage grids for regional distribution of electricity. Proof of concept for the Layered Energy System.
	ABB	Supplies the necessary equipment for local energy market.
	EWF Blockchain	Provides an energy-focused blockchain platform.
	Enervalis	Provides software for decentralised energy systems.
Jouliette at De Ceuvel	Local community at De Ceuvel	Partner, producers and consumers of electricity.
	Alliander	Alliander is the applicant of the pilot project. In the Dutch energy systems, Alliander is responsible for operating low and medium voltage grids for regional distribution of electricity.
	Spectral	Partner, technical provider. Provides a new platform for setting up local energy markets based on blockchain technology.
Powerpeers	Small-scale prosumers	Partner, producers and consumers of electricity.
	Powerpeers	Powerpeers provides technological solutions for decentralised energy systems such as an online platform.
	Vattenfall	Parent company of Powerpeers, also acts as a balance responsible party in the Dutch energy systems. Vattenfall is responsible for balancing acquisition and sales of electricity.
PowerToShare	ToBlockchain	Technical provider, offers technological solutions for decentralised energy systems such as an online platform.
Others	Tennet	Balancing the high voltage grid via home storage or electric vehicle cars.
	Aggregator	Offers to manage demand response via energy storage or incentives.
	Energy21	Offers expertise in the sustainable energy ecosystem.

C.3 Trends and Developments in the Dutch energy sector

C.3.1 Diverging Interests

Transformation towards a low-carbon energy system involves a wide range of actors to deliver new and innovative solutions. Efforts to transform the current energy system encompass changing to not only energy prices and technologies but also social and economic arrangements that are built surrounding energy production, distribution, and consumption. Such efforts imply possible adjustments of current energy arrangements to accommodate energy transition. Nevertheless, interactions between these factors are complex, multifaceted, and uncertain. This section focuses on drivers from a different group of actors in the electricity system that influence the integration of decentralised energy generation into the power system.

The role of society in the energy sector has long been considered as a critical factor to enable the transition towards a decentralised and low-carbon energy system. Within the power and utility sector, the trend towards locally generated electricity is facilitated employing technological innovations in the energy sector such as solar photovoltaics (PVs), windmills, energy storage, or loads management. For the case of solar PVs, the declining costs of solar modules, policy support, as well as technological improvement, have been regarded as the primary drivers to the rapid expansion of solar PVs (International Renewable Energy Agency, 2018). As a result, the means to produce energy independently and participate in an energy market have become accessible for small-scale producers such as prosumers (Koirala et al., 2016; Stedin & Energy21, 2018). At the same time, a societal change towards renewable energy generation has also caused the emergence of energy communities[1]. These initiatives facilitate individuals, who share common values, to organise themselves in order to gain more control over energy supply and reduce dependence on fossil fuels (see, e.g., Powerpeers, 2019; Sonnen Group, 2019; Stedin & Energy21, 2018).

Nevertheless, renewable energy production depends on the availability of renewable energy sources which may not always be available. Combined with planned electrification of heating system and transport sectors to reduce CO_2 emission (Moraga & Mulder, 2018), the explosion of energy demand may cause an imminent capacity problem on the network. In the past, grid reinforcement is generally considered as the solution for this issue (Koirala et al., 2016; R. Moreno, Street, Arroyo, & Mancarella, 2017). However, with an evermore increasing renewable energy generation, grid reinforcement may not be the most cost-effective solution as it is highly capital intensive. Instead unlocking flexibility assets at the household level such as demand response[2], energy storage, and flexible loads are considered as cheaper options to assist grid balancing (Albadi & El-Saadany, 2008; Klaassen, 2016; Ponds et al., 2018).

Flexibility[3] has become a subject of intense study due to its potential, among others, to reduce system costs and improve reliability. In recent years, efforts have been made to unlock flexibility at the households level. In the Netherlands, several projects are executed by grid operators to investigate the potential use of flexible local assets in order to provide higher capacity in the power grid network (see, e.g., Stedin & Energy21, 2018; TenneT, 2019b). At a global level, efforts are currently being made to manage flexibility internationally, and cross-border trade is expected to become a dominant flexibility option in the future. Such an opportunity can benefit a multitude of actors in the electricity system. However, its size will largely depend on available interconnection capacity and the management of domestic flexibility options (ECN, 2017). As a result, the transformation of flexibility landscape leads to new opportunities to offer new services which may translate to new actors in the energy system.

Summary

To conclude, the drivers towards decentralised energy system are originated from, among others, increasing decentralised energy generation, a societal change towards renewable energy generation,

[1]In the research, energy communities do not always imply that individuals need to live in the same area. This notion also includes those who are involved in the "virtual" energy communities.

[2]Demand response can be defined as the changes of energy consumption patterns in response to the variations of electricity prices overtime or incentive payments offered to alter energy consumption during peak loads (Albadi & El-Saadany, 2008; Klaassen, 2016).

[3]Flexibility concerns the ability of the electricity system to cope with variations of energy supply and demand.

and possibly new opportunities (flexibility) to assist grid balancing. Depending on which actors are taking the lead, different approaches are observed. For the individuals or energy communities, the development of a decentralised energy system is seen as a way to achieve autarky and more control over supply. On the other hand, incumbent actors such as grid operators are interested in developing an energy system that can solve challenges on the distribution grids (e.g. reliability). A more elaborate explanation of this information is explained by linking drivers and socio-technical systems in the following section.

C.3.2 Socio-technical developments in the energy system

Following the key drivers outlined above, a wide range of decentralised energy systems may emerge depending on the challenges that the initiators want to tackle. This section aims at providing current developments of decentralised energy systems based on the dynamics of socio-technical systems.

Technological developments in decentralised energy systems

Technological innovations in the power system have been regarded as the key enablers of transition towards low-carbon energy, which are primarily used to unlock potential opportunities in the energy sector for those who can adapt and scale fast. Technological innovations do not necessarily come with a brand new invention; rather, they also include those technologies that have potentials to solve existing power system issues radically. To a large extent, the integration of digital technologies has been reshaping the energy sector (Bayram et al., 2014; Jogunola et al., 2017; Sousa et al., 2019). This section delineates this aspect based on current trends in the energy system.

The rise of connected loads through the use of technological innovations in the energy sector plays an important role in the integration of decentralised energy generation into the existing power system. In the technological infrastructure, the upgrade of the current power grid with Information and Communications Technology (ICT) resulting in the so-called smart grid system. Such a system is perceived as a potential solution because it accounts for volatility of energy supply and a rising number of decentralised energy generation through the digitalisation of energy-related information (Milchram, de Kaa, et al., 2018; Shaukat et al., 2018). As the system becomes ever more intelligent, there is a possibility for efficiently deliver a secure, sustainable, and economical supply of energy. To illustrate, such a development enables the digitalisation of energy information such as production and consumption as well as data exchange between devices and actors in the system. Combined with the integration of digitalised online platforms, there is a possibility to distribute their excess energy to manage demand and supply (Kloppenburg & Boekelo, 2019; Morstyn et al., 2018; Zhang et al., 2018).

In recent years, technological innovations in the energy sector have stimulated multiple small to medium pilot projects to facilitate the integration of decentralised energy generation into the existing power system. For instance, the management of flexible loads and peer-to-peer energy trading. Based on these developments, there are two contrasting ideas with regard to the location of energy supply. The first one relates to the integration of decentralised energy generation arranged at the community level. Although this setting facilitates the possible active involvement of consumers and prosumers, it is restricted to the geographical location of the end-users and generally aims at solving regional technical constraints (see, e.g., ICT, 2019; Stedin & Energy21, 2018). The second one focuses on the distribution of energy that is not bound by the geographical location. It allows prosumers and consumers to actively engage in commodity trades by way of ICT's integration into the energy system. Therefore, this arrangement does not rely on the vicinity between energy producers and consumers (see example, e.g., Powerpeers, 2019; Sonnen Group, 2019).

As aforementioned, the developments of technological innovations in the energy sector can potentially unlock a whole new range of opportunities for a multitude of actors. Such developments imply that not only consumers/prosumers are changing but also other actors involved in the developments. With regard to utility companies, they are moving towards adopting new business models and providing new services to facilitate the growth of decentralised energy generation (Koirala et al., 2016). The next section presents the dynamics of social aspects (actors and institutions) caused by technological innovations in the energy system.

Social aspects in the developments of decentralised energy systems

As described previously, a societal change towards decentralised energy generation opens up opportunities for the local governance of energy production. Additionally, new actors and services emerge to enable the integration of decentralised energy generation into the existing power system. As a result, the shift towards decentralised energy systems involves a changing of actors' network in the energy system, including regulated bodies, utilities, prosumers/consumers, and service providers. This section explains the societal dynamics in the developments of decentralised energy systems.

During energy transition, technological innovations (e.g., IoT and digitalised platforms) and social innovations (e.g., energy communities) appear from different network positions in the energy system. These developments represent different actors' opportunities to access new resources such as knowledge and information that are essential to the establishment of new energy products or services. Subsequently, the integration of decentralised energy generation into the existing energy system requires a suitable network structure that represents the nature of distributed energy production and consumption (Gui & MacGill, 2018). Additionally, principal actors who occupy certain positions can influence the shape of this network of actors in order to obtain their desired outcomes. At the community level, new services may emerge to enable communities in order to obtain their sustainability goals. For instance, peer-to-peer online trading platform emerges to allow direct communication between prosumers and consumers (see, e.g., Mengelkamp et al., 2018; Powerpeers, 2019). Such a service makes its way into society by promising higher energy efficiency, providing equal access to sustainable and affordable energy, and democratising access to renewable energy (Kloppenburg & Boekelo, 2019; Sousa et al., 2019). On the other hand, new actors such as aggregators may emerge to manage flexible assets. Such a service is beneficial to the grid operators as it can offer more capacity for the electricity grid (Gkatzikis et al., 2013; Koirala et al., 2016; Parag & Sovacool, 2016; Stedin & Energy21, 2018). According to Parag and Sovacool (2016); Saboori et al. (2011); Stedin and Energy21 (2018), the aggregation can be executed by incumbent actors who have been governing the energy sector or new emerging actors that are formed as a result of changing in the network structures.

In both cases, a different network of actors may emerge due to different initiators and drivers. A fully peer-to-peer structure is characterised by the lack of a central agent overseeing the transactions in the network (Parag & Sovacool, 2016). Instead, peers directly negotiate with each other over the price and volume of the energy based on a predefined trading scheme (Sorin et al., 2019; Sousa et al., 2019). This service is oftentimes offered by private companies to support communities in order to achieve their goals. Meanwhile, the aggregation of flexible assets implies that a brokerage system exists to manage flexible assets as this service appears to offer ancillary services to the grid operators. Incumbent actors take the lead towards the integration of distributed energy generation into the existing electricity system (see, e.g., Stedin & Energy21, 2018). In this line of reasoning, it is essential to understand the primary drivers of each actor as well as the initiators in the development of decentralised energy systems. Such information gives a profound knowledge of how principal actors influence network of actors. Additionally, it also affects the emergence of new actors and services in the system.

Another development is the emergence of new pricing strategies in the Dutch energy market. First, utilities are starting to offer an energy product that has fixed kWh rate. In the event of the underlying wholesale index drops, the price for electricity will decrease proportionally. Therefore, consumers have the assurance of the electricity price and the possibility of a lower tariff. Second, a fixed monthly fee irrespective of consumers' energy consumption. Such a pricing mechanism is normally accompanied by a contract period and applied efficiency measures, which may reduce total energy consumption.

Summary

The aforementioned sections have highlighted socio-technical developments in the Dutch energy sector. The grid advancements and digitalisation of energy-related information have opened up opportunities for new actors and services to support the integration of decentralised energy generation into the power system. Such developments have a domino effect on the network of actors.

C.3.3 Barriers and challenges

As described in previous sections, the transformation towards decentralised energy systems carry both challenges and opportunities. This section delineates the barriers and challenges of the integration of decentralised energy generation into the existing power.

While decentralised energy systems offer many potentials solutions to current issues in the electricity systems, its primary disadvantage is the lack of economies of scale (McKenna, 2018). As described previously, the development of decentralised energy generation goes hand in hand with the trends towards local energy generation which is motivated by, for instance, more control over supply and their growing awareness towards dependence on fossil fuels. Nonetheless, without ancillary services such as energy storage and loads management, the scope of optimising the use of locally produced energy is limited (Luthander et al., 2015). This is due to the fact that such technologies, especially energy storage, are still considered expensive and have uncertain effects on the claimed advantages. Notably, if investment costs are compared against the advantage of feed-in tariff[4] or generating power from conventional resources (van der Stelt et al., 2018).

Apart from the socio-economic point of view, barriers are also present as a result of liberalisation in the energy sector. First, the liberalisation of the energy sector was created to stimulate competitions between energy suppliers; however, such changes also carry multiple negative consequences. For instance, the government put stricter regulations to safeguard the delivery of the energy which, at times, may conflict with the implementation of decentralised energy system (Bruijn & Dicke, 2006). Another primary issue is the licensing requirement for prosumers. According to Article 95a of the Elektriciteitswet 1998, a prosumer does not require to obtain a suppliers license to consume and produce their own energy.[5] However, a suppliers license from the Authority for Consumers Markets (ACM) is required if prosumers wish to supply energy to small or medium consumers (Butenko, 2016). Such a restriction may restrict the involvement of small-scale producers in the electricity market.

C.3.4 Conclusion

The aforementioned sections reveal several factors that may lead to diverse scenarios of decentralised energy systems. The primary driver for the integration of decentralised energy generation into the existing power system influences which challenges the actor(s)/initiators want to tackle. Depending on their desired outcomes, principal actors may influence the structure of the decentralised energy systems. For the socio-technical perspective, there are multiple trends observed in the Dutch energy sector. First, the developments and advancements of technological infrastructure allow digitalisation of energy-related information which enables new actors and services emerge to support decentralised energy systems. Second, the integration of the digitalised platform into the power system has unlocked the potential distribution of energy that is not restricted by geographical

[4]The primary reason behind such stagnation is due to current regulation, *Salderingsregeling*, that provides no incentives for small-scale energy producers to store their energy.

[5]Wet van 2 juli 1998, houdende regels met betrekking tot de productie, het transport en de levering van elektriciteit (Elektriciteitswet 1998). Retrieved March 15, 2019, from https://wetten.overheid.nl/BWBR0009755/2019-01-01

location. However, such an initiative may have an impact on grid management, resulting in different types of actors and services supporting this initiative.

D. The Dutch Electricity System: The Status Quo

The Dutch electricity system was built upon centralised manner to accommodate centralised energy production. Its energy supply chain is characterised by a high level integration of extracting, processing, and transporting non-renewable energy sources from power generation to end users (Stedin & Energy21, 2018). Such a system was developed because it induced efficient resources allocation and generated substantial economies of scale to ensure the reliability of the energy system (Klaassen, 2016). Nevertheless, the emergence of decentralised energy systems may impose some challenges to this well-established system because the current energy system is not suitable for decentralised energy generation. In order to understand these challenges, insights into the current organisation of the power system is required.

Section D.1 describes the current Dutch energy system based on its historical transition and three different layers that make up the system. Next, **Section D.2** the current actors' roles and resources in the energy system are presented. The third section of this chapter provides an inventory of current decentralised energy projects in the Netherlands to identify stakeholders involved in the developments of decentralised energy systems (**Section C.2**). The last section presents examples of safeguarding mechanism in the current Dutch energy systems (**Section D.3**).

D.1 The Dutch Energy System

The liberalisation of the Dutch electricity market has started in 1998 following a European treaty made in 1996. At that time, the Netherlands was one of the front runners to liberalise electricity markets by the adoption of the Electricity Act (E-Act) in 1998. The primary objective of the liberalisation in the electricity sector was to provide consumers with a freedom of choice with regard to their preferred energy suppliers. Such a regulatory framework was expected to increase competition in the energy sector in return for a lower energy price and higher energy efficiency. Additionally, the liberalisation of the electricity market aimed at providing incentives for suppliers to invest in renewable energy to stimulate the growth of renewable energy generation (Klaassen, 2016). To further solidify liberalisation in the energy section, the Electricity Act was amended to unbundle the ownership of generation, transmission, and distribution of electricity. As a consequences, energy suppliers had to be independent from grid operators and a new institution was created to manage and operate high voltage grid known as Transmission System Operator (TSO).

Although the Dutch energy system is liberalised, some physical infrastructure used to transport electricity (transmission and distribution networks) are still monopolised due to network effects and need for central coordination. Thus avoiding the possibility of commercial parties exploit control over monopoly functions (de Vries et al., 2017). Combined with the introduction of the Amsterdam Power eXchange (APX, which has since been renamed to Epex Spot), the current energy value chain in the Netherlands is represented in Figure D.1.

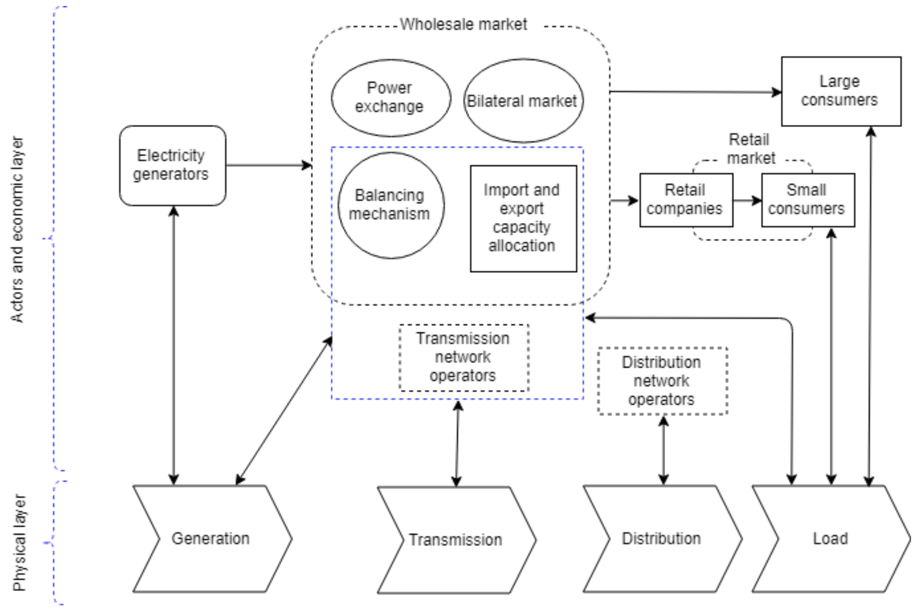

Figure D.1: The Dutch energy value chain (de Vries et al., 2017).

D.1.1 Electricity System Description

As described briefly in Chapter 1, the liberalisation of the Dutch electricity increases the complexity of the system. To understand the complexity of the current Dutch electricity system, the following section provides a description of the system to identify actors who are involved in different parts of the value chain. It is important to mention that the following section describes the system in a rather detailed manner in order to appropriately identify actor(s) and their function(s) in the system.

Traditionally, the conventional energy value chain starts with the generation of electricity by electricity producers which is produced by centralised energy generators. There are two ways producers sell their produced power via the markets or sell their produced electricity to their own consumers. In the latter case, the energy producers are also energy suppliers to the end-users. As for the former case, there are three primary markets in the Netherlands, bilateral/forward market, spot market, and balancing market (real-time). Bilateral/forward market emphasises on long-term duration via Over-the-Counter (OTC) contracts or future exchanges. This market is generally used by large consumers (with connections bigger than 3x80 Ampère) to buy electricity directly from the energy producers. Electricity prices and duration of these contracts are generally kept confidential between producers and consumers. This market is operated by the ICE index. In the spot market, electricity is traded in short-term. There are two different types of markets: the day-ahead and the intra-day markets. These markets allow suppliers and trades to bid on electricity. Furthermore, electricity is traded in blocks with specified delivery times which can range from 5 minutes to

24 hours in advance. Here, market operator performs a market clearing procedure to determine equilibrium market and clears the prices and volumes. Meanwhile, the balancing market emerges as a result of market reform and is used specifically for balancing the system. As this report focuses on small-scale consumers, the bilateral market is omitted in this section.

The next two processes in the value chain involve the distribution process of the electricity which splits into two parts, transmission and distribution. The electricity that is generated by conventional power plants is distributed via a transmission grid. As the electricity from conventional power plants is generally transported at long distances, transmission occurs at high voltage to reduce energy losses and thus increasing energy efficiency (von Meier, 2006). The Dutch transmission network is owned and operated by a Transmission System Operator (TSO), which has three primary tasks: (1) to balance the electricity that is injected or withdrawn in the transmission network, (2) to manage import capacity, and (3) to manage the transmission network (de Vries et al., 2017). These tasks are related to the management of the transmission infrastructure such as providing sufficient transmission capacity, maintaining stability of the network (voltage and frequency), and managing congestion.

The market reforms caused by the liberalisation of the energy sector entails the need to maintain balance between supply and demand due to competition at the end-user and producer levels. According to von Meier (2006), network balancing is the most essential technical characteristic of the power systems. Maintaining the balance between demand and supply is required to prevent disruption of energy services. As a result, "balancing responsibility" is implemented for all connected users in the Dutch electricity system (Tennet, n.d.). In essence, this programme implies that connected parties must inform the grid operators regarding their planed electricity production, consumption, and transportation needs. The E-programs submitted by each connected party are used by the TSO to determine the volume of electricity required for each time slot to to maintain reliability of the grid.

Individuals can set up these programmes by themselves or delegate such a responsibility to authorised Balancing Responsible Parties (BRPs). In practice, supply companies fulfil this role on behalf of small consumers by entering into contractual agreements that stipulate the volume of electricity bought and sold. These BRPs submit the energy programs (E-programs) to the system operator for each hour of the next day. Ideally, the balancing responsibility programme promotes continuous balance of energy supply and demand. Nevertheless, forecasting errors and unpredictable consumption behavior entail that energy supply and demand is not balanced all the time. As a system operator, TSO maintains physical balance in real-time by procuring reserve power from energy generators that can fulfil the required capacity on short notice (dispatching) via balancing market (real-time). Market participants that offer such balancing services are known as balancing service providers (BSPs). These actors are generally a subset of energy producers or large industrial consumers (Voulis, 2019). In the balancing markety, BSPs make bids and offers to buy and sell electricity. Generally, at a price that is higher than their operational costs (Tanrisever, Derinkuyu, & Jongen, 2015). Meanwhile, the TSO uses the submitted E-programs for the settlement of imbalances.

The distribution network connects the transmission network and the end-users. The primary differences between the transmission network and distribution network are twofold. The transmission network adapts a meshed network whereas the distribution network is mainly radial and is thus hierarchical (Voulis, 2019). Consequently, the distribution grid is operated at different voltages, medium and low voltage grids von Meier (2006). The Distribution System Operators (DSO) are responsible for maintaining the distribution grid, providing connections to the grid (for small to medium consumers), overseeing physical delivery of electricity, and administer of electricity exchange through the distribution grid. In the Netherlands, each DSO manages the distribution network in their own specific area. This setting implies that the consumers are unable to select their own DSOs. Due to their roles in the physical delivery of electricity, DSOs are responsible for the data management of metered data. This is further discussed in Section D.1.2.

To conclude, this section has provided four primary segments related to the technical layer in the power system along with actors that are responsible for each particular segment. In the technical layer, the most important technical characteristic is the need to always maintain the balance between energy supply and demand. As described in this section, the introduction of balancing responsibility is meant to ensure that each party connected to the grid maintain the balance of their own supply and demand in order to prevent disruptions of service.

D.1.2 Information layer

The above section has highlighted the load flow in the electricity network. One particular importance that can derive from the above section is the need for data management. This section describes the information layer in the current Dutch energy system with the focus on energy-related data management.

Along with balancing responsibility, metering responsibility also emerges as a result of the market reforms. Metering responsibility entails that each party that purchases electricity from the grid is responsible for measuring how much they consume and disclose this information to the grid operator. Consumers can fulfill this metering responsibility themselves provided that they have been authorised to do so. They can also outsource their metering responsibility to a recognised third party. These metering companies also install and maintain the meters (TenneT, 2019a).

In the current ecosystem, the DSOs collect data four types of data: (1) identification of point delivery (identification of the meter and its connection point), (2) contract and consumer data (first day of contract with a specific energy supplier, and name and address of consumer), (3) consumption data, and (4) grid data. In practice, the collected data is used for a number of purposes:

1. Metering point administration
2. Supplier switching
3. Billing data Grid planning and operation
4. Settlement

In the Netherlands, energy data management is carried out in a centralised access and decentralised storage *(EDSO, 2014)*. It implies that the data collected from all parties connected to the grids are being controlled by a clearing house. Such a clearing house is regulated to ensure non-discriminatory access between market parties which is necessaries for competitive markets.

D.2 Roles and Resources of Key Actors in the current Dutch electricity system

The aforementioned section has highlighted elements that make up the power system in the Netherlands. Based on the above description, the following section provides an overview of actors' roles and resources in the current Dutch Energy System.

Transmission System Operator (TSO)

In the current Dutch energy system, as grid operator under the Dutch 'Elektriciteitswet' (E-wet), has three primary tasks, namely providing power transmission services, system operators, and facilitating the energy market. Therefore, TSO is responsible for, among others, maintaining a stable power system operation (including network balancing) through a transmission grid in a geographical area, managing import capacity, and balancing the electricity supply with demand (de Vries et al., 2017; ENTSO-E, 2015). Such tasks are related to two primary activities, network management and maintaining energy balance on the grid.

Additionally, TSO, as the System Operator, assumes statutory duties such as system services, secure a safe and reliable energy supply, import and export electricity, and maintain the system of programme responsibility parties. These programme responsibilities are related to other actor in the system which will be discuss later in the respective actor.

Distribution System Operators (DSOs)

While TSO is responsible for the high voltage, the DSOs are responsible for the operation, maintenance, and development of the distribution network in a given area and, if applicable, its interconnections with other distribution networks (M. Buth, 2018; Lampropoulos et al., 2018). Furthermore, the DSOs are responsible for voltage control, load curtailment, and grid reinforcement within its perimeter. Similar to TSO, DSOs are state-owned organisations and are not allowed to undertake any activities that may be in conflict with the interests of the network operation and management.

As the DSOs connect transmission lines to the end-users, DSOs provide connections to the grid and act as administrators to the electricity exchange conducted on the grids. As a result, DSOs play important roles in data management. The DSOs collect, cross-references, and process data for market participants and regulators *(EDSO, 2014)*. This task are associated with the metering point administration, changing suppliers, billing for consumption of electricity, and consumers data (e.g., real-time production and consumption), and settlement *(EDSO, 2014)*.

Balancing Responsible Parties (BRPs)

The liberalisation of the Dutch electricity market permits each participant to choose to choose their own suppliers. Consumers and energy suppliers (retailers) have contractual agreements that specify how much electricity they are buying and selling. However, the actual amount of electricity consumed or traded may differ from the contracted amount. As a result, programme responsibility is introduced. The programme responsibility entails that each entity connected to the physical grid and actively involves in the electricity markets is required to balance their own energy supply and demand in order to avoid any disruption (Tennet, n.d.). This task can be carried out by themselves or assign the responsibility to authorised Balancing Responsible Parties (BRPs). At the end of the day, BRPs submit e-programs to system operator that indicate planned consumption/production of their contracted connection points. This information is required to enable grid balancing. The difference between the actual and the planned volume is by TSO. Most of the time, energy suppliers are also BRPs, but this is not mandatory (M. Buth, 2018).

Energy producers (Centralised)

In the energy value chain, the (centralised) energy producers generate electricity without directly supplying it to the end-users. Their generated electricity is fed into the transmission lines to be distributed to the end-users. Apart from generating electricity, energy producers also facilitate balancing on the transmission lines by providing flexibility to adjust their energy production based on energy demand. This role is enabled by the ownership of large power plants. In the Netherlands, a large amount of electricity is generated via natural gas and coal power plants.

Energy Suppliers

In practice, energy suppliers oftentimes have their own power plants and, therefore, assume a role as energy producers. However, for the sake of clarity, both actors are separated in the research. The role of energy suppliers is to source, supply, and invoice electricity to their customers. As mentioned previously, consumers and suppliers enter into commercial agreements for the procurement of energy (Universal Smart Energy Framework, 2015). The roles of energy suppliers are enabled when metering points of their consumers are assigned to them (as cited in Lampropoulos et al., 2018). Additionally, in order to supply electricity, energy suppliers need a specific license issued by the ACM (through delegation by the Minister of Economic Affairs).

Consumers

Consumers are individuals who buy and consume electricity from the main grid.[1] Consumers can be categorised based on their connection volume. Large consumers (with connections bigger than 3x80 Ampère) are able to buy electricity directly in the wholesale markets. Meanwhile small-scale consumers buy electricity through energy suppliers via commercial agreements (Mulder, 2017).[2]

Market operators

Market operator is responsible for the organisation and administration of electricity trades and settlements between market participants (e.g., energy producers, energy suppliers, or consumers). In relation to the balancing market, the market operator receives the bids from BRPs and determines the energy price for balancing after applying technical constraints from the system operator (ENTSO-E, 2015). In the Netherlands, the wholesale markets are divided into three categories based on different time intervals:

Metering company

A metering company supplies, installs and maintains the electricity and gas meter, collects power and gas consumption data and sends it to the grid administrator. Metering companies are only responsible for large-scale consumers (i.e. with connections bigger than 3x80 Ampère (ca 100.000 kWh)): the consumption of small-scale consumers is measured by DSOs via their suppliers. Metering companies used to be part of system operators but have become separate entities since the liberalization.

Data facilitator

The data facilitator expedites the administrative data exchange between market parties, such as system operators, metering companies, BRPs and suppliers. Furthermore, the data facilitator safeguards free market processes and enables an administrative platform for consumers and suppliers which facilitates the switching of suppliers for consumers. In the Netherlands, the data facilitator is called Energie Data Services Nederland (EDSN).

Autoriteit Consument en Markt (ACM)

ACM supervises the compliance of the Electricity and Gas Law. The role of ACM is to protect energy customers interests and safeguard competition in the market. ACM is enforcement, with the objective to prevent and resolve market and energy customers' problems. Furthermore, ACM also supervises regulations of third-party access and tariffs related to the Dutch electricity market. ACM has powers to impose sanction upon infringements of the Acts.

Ministry of Economic Affairs

Ministry of Economic Affairs supervise the compliace of the Electricity and Gas Law with regard to security of supply, network access conditions, and tariff structures. The Ministry of Economic Affairs plays an important role in balancing interests to accommodate flexibility services in the market. It has capacities to amend laws (e.g. for tariff distribution, data privacy, or competition in the market) and access to perform capital injections by offering several funding options (e.g. incentives or subsidies) (SGTF-EG3, 2015).

D.3 Safeguarding public values in the Dutch energy system

Conventionally, the Dutch energy sector has emphasised on the use of hierarchy and market mechanisms to safeguard public values. The hierarchy is used to impose rules and regulations

[1] Here consumers only hold a role as consumers to enable differentiation between the current Dutch energy market and the future decentralised energy systems.

[2] In the research, consumers are treated as a single entity type and are not differentiated based on their connection scale.

to induce commitments from market participants. Meanwhile, market mechanisms are used to stimulate new market opportunities. The following section provides an overview of safeguarding mechanism by hierarchy and market mechanism used in the current Dutch energy sector. In the Netherlands, the 1998 Electricity-Act (E-Act) is used to regulate the Dutch electricity system. This regulatory framework defines the formal relationship between actors in the energy systems and their corresponding tasks. As opposed to regulatory framework, safeguarding through market mechanism implies that the government uses market forces to ensure the realisation of public values. In the current Dutch regulatory frameworks, there are two exemplary regulatory frameworks that can be classified as safeguarding via market mechanisms, the SDE+ and the Salderingsregeling.

The SDE+ is an operating grant aims at increasing the production of renewable energy in the Netherlands. The incentive is an operating subsidy for the production of renewable energy and not for the acquirement of installations. SDE+ compensates the difference between the cost of renewable energy and the cost of fossil-fueled production over different periods of time, 5, 12, or 15 years depending on used technology. Meanwhile, the Salderingsregeling is especially essential for the development of decentralised energy generation, especially for small-scale consumers. This regulatory framework allows prosumers to consume their excess energy anytime regardless of the electricity prices. To illustrate, if a prosumer feed 100 kWh into the grid during summer, he/she can use this excess energy during winter time without worrying about the price differences between summer and winter time. For the settlement purpose, the energy supplied to the grid is subtracted from his/her total energy bill based on the metered reading. However, there are two main limitations of Salderingsregeling. First, there is a limit on how much kWh "substracted" per year, which differs from one to another. Energy supplier will calculate how much electricity can be obtained for each prosumer according to their total usage and contribution. For instance, an energy supplier supplies a prosumer with 200 kWh, and the solar panels generate 1500 kWh. As we can never offset more than the amount of energy supplied by your supplier. It means the excess of 700 kWh will be compensated via remuneration.

There are two primary issues with this system. First, the net metering implies that costumers who feed in electricity have a privilege to evade paying energy taxes. This is because the current energy taxes are calculated as a fixed percentage of the delivered electricity from energy suppliers to consumers. Furthermore, the investment costs associated with the use of solar energy imply that solar panels are mainly adopted by people who have certain financial level. Consequently, only a part of the society is able to afford installing solar panels. Others who do not have feasible means to have solar panels need to pay additional costs that may emerge as a result for the integration of decentralised energy generation into the existing power systems. Thus, this regulatory framework indirectly support those who are able to install solar panels. Second, this regulation does not provide enough incentives for the adoption of energy storage or energy trading. Particularly, because the fixed price applied to the electricity produced by small-scale producers implies that it is beneficial for small-scale producers to feed in electricity back to the grid instead of paying for additional costs associated with energy storage.

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E. Changing Roles and Resources of Actors

The following section explores the dynamics of actors' roles and resources based on the current Dutch energy system and the proposed scenario.

Consumers

In the current electricity system, the primary role of consumers is to buy and consume energy via contractual agreements with conventional energy suppliers. However, as conventional energy suppliers would be replaced by ISPs, consumers would rely on ISPs to buy and consume energy directly from producers via online trading platform. This shift indicates that consumers would require to set their own preferences for trading purpose. Additionally, consumers could assume additional roles of flexibility resource providers for the "virtual" market. Such a role are assumed if the costumers have access to technological innovations via contractual agreements with ISPs. Additionally, they are required to have decentral assets such as EVs or home automation (domotica). These decentral assets should also be connected to the smart device provided by ISPs for monitoring purpose as well as the activation of flexibility service. As active players in the electricity markets, consumers would also require to be balance responsible, this role is delegated to ISPs based on contractual agreements between ISPs and consumers.

Table E.1: Potential Changes to Consumers' Roles and Resources

Current position	Buy and consume electricity.
Future position	Future roles: Additional role as flexibility resource providers
	Resources: Flexible assets such as EVs or domotica. Additionally, they are required to have access to services provided by ISPs.

Prosumers

In the current system, it was assumed that prosumers are not yet defined. In the future scenario of decentralised energy systems, prosumers could assume multiple roles. With regard to electricity generation, prosumers could assume the role of energy producers to supply consumers within their networks. Similar to the previously mentioned consumers role, prosumers could assume the role of flexibility resource providers. Such a role is realised by the ownership of distributed energy resources that are connected to smart devices provided by ISPs. By and large, prosumers would become important market actors when they increase the scale of electricity production as well as flexible assets. Similar to consumers, prosumers are required to have access to services provided by ISPs to assume their roles.

Table E.2: Potential Changes to Prosumers' Roles and Resources

Current position	Produce and consumer own electricity.
Future position	Future roles: Apart from being consumers, prosumers would assume the role as energy producers as well as flexibility resources providers
	Resources: Distributed energy resources such as solar PV, energy storafe, and domotica. Additionally, they are required to have access to services provided by ISPs.

Transmission System Operator

In the current power system, the TSO is responsible for the operationalisation of the transmission lines. Therefore, it is responsible for the security of the national high voltage as well as its maintenance. To ensure system stability, TSO uses data on current and projected power generation provided by balance responsible party in order to plan balancing required on the transmission line. Additionally, it uses capacity that is internationally traded and will be transported via interconnectors. However, the roles and responsibilities of TSO are likely to shift in decentralised energy systems. In relation to the procurement of balancing services provided by the coalition of prosumers and consumers (via ISPs), TSO plays an important role in enabling the integration of such services for balancing the transmission lines. As a result, the coordination between TSO and ISP is the key for the integration of local balancing services.

Departing from the stability of the system, TSO is also responsible for transmitting electricity generated from centralised power plants over longer distances. However, a high penetration of decentralised energy generation means that electricity would no be longer to be transported over longer distances as the generation is oftentimes close to the consumption point. Adhering to this line of reasoning, the amount of electricity to be transported to small-scale consumer would decrease.

In relation to the DSO, it is likely that a higher coordination between DSO and TSO is required. The primary reason for such a change is due to the emergence of small-scale prosumers at the regional level that could potentially cause congestion at the distribution lines. As a result, the DSO may require to be involved in balancing the regional grid. At the moment, balancing services is the responsibility of the TSO.

Table E.3: Potential Changes to TSO' Roles and Resources

Current position	As a system operator, TSO is responsible for the security and operation of the national high voltage grid.
Future position	Future roles: In the future, the role of TSO remains the same. However, TSO and DSOs will likely to share balancing responsibility as many decentralised energy occurred at the regional level which imply that DSOs would require to take balancing responsibility.
	Resources: Traditional resources of TSO will likely remain the same.

Distribution System Operator (DSO)

While the TSO is responsible for the transmission line, DSOs would likely shift towards becoming system operator at the distribution levels. The major tasks of DSOs are network planning, network operation, and managing balance at the regional level (low and medium voltage grids). For this reason, DSOs are the central player for the integration of decentralised energy generation into the power system. First, DSOs could require to balance the distribution grid. To illustrate, the current role of the TSO is to balance the power system, whereas DSOs are responsible for grid congestion. Such a shift creates an additional linkage between DSO and TSO caused by the seemingly more complex energy system. Furthermore, the procurement of balancing services via ISPs implies that DSOs could become market facilitator. It is essential that the DSOs promote equal access to all market participants in the provision of grid balancing.

In relation to the transactions occurred via ISPs platforms, the DSO would need to oversee all transactions to ensure that they are within grid technological constraints. This task could be assumed by DSOs when they have sufficient information about transactions occurred in the network. Therefore, DSOs would need to coordinate with ISPs with regard to energy trades for the distribution lines. In this sense, DSO is one of many actors being affected by the emergence of P2P energy trading as trades between end-users are conducted at the regional level (medium to low voltage).

Table E.4: Potential Changes to DSO' Roles and Resources

Current position	DSO is responsible for the operation and maintenance of the regional medium to low voltage.
Future position	Future roles: TSO and DSOs are likely to increase cooperation with regard to balancing services. Additionally, DSOs are required to oversee transactions occurred in the online platform. Therefore, it is essential for DSOs to establish a shared database with ISPs.
	Resources: Traditional resources of DSO will likely remain the same. Nonetheless, there are additional resources required by DSOs in order to enable their new roles with regard to energy trading. For the energy trading, DSOs are required to have access to ISPs' database in order to oversee transactions in the platform.

Balance Responsible Parties (BRPs)

In the current system, the primary task for BRPs are to balance their portfolio by way of establishing bilateral agreements with the energy generators or purchasing via wholesale markets. Compared to the scenario proposed in the previous chapter, the role of BRPs in the electricity markets would likely remain the same. However, the emergence of new entrants such as prosumers and consumers via ISPs could open up a new business opportunity for BRPs. A new role is proposed for BRPs to support the emergence of these new actors by providing local balancing services via ISPs.

Table E.5: Potential Changes to BRPs' Roles and Resources

Current position	In the current practice, energy suppliers generally assume the role of BRPs. However, this is not mandatory. BRPs are responsible for balancing their own portfolio and planning of the daily usage.
Future position	Future roles: Local balancing services for consumers and prosumers via ISPs.

	Resources: Similar to traditional BRPs, in order to assume the role of local balancing services, the BRPs are required to have financial resources. Additionally, they need to have information about transactions occurred in the network for the e-programs.

Energy producers

Here energy producers refer to actors who produce electricity that is transmitted via transmission line. In the current electricity system, the energy producers are responsible for generating electricity to meet the energy demand. Additionally, they are also required to provide balancing on the grid by adjusting their production. In the future scenario of decentralised energy system, the roles of energy producers would likely remain the same. However, they may have less contribution to meet the demand of small-scale energy producers. With the emergence of ISPs, small-scale producers and consumers who have contractual agreements with the ISPs would have less dependence on the energy producers. In time when renewable energy generation is less than energy demand, the energy producers are required to supply additional energy based on the contractual agreements between energy producers and ISPs.

Table E.6: Potential Changes to Energy producers' Roles and Resources

Current position	Generate electricity to meet energy demand and provide flexibility to the current electricity system.
Future position	Future roles: The function of energy producers would likely remain the same. However, increasing volume of decentralised energy generation implies that there would be less energy distributed to small-scale consumers.
	Resources: The resources of energy producers remain the same.

Energy suppliers

Here energy suppliers refer to current incumbent actors who provide electricity to the end users and measure the electricity that is used by them. As energy suppliers can also be energy producers, these actors may become ISPs because of their tangible resources.

Table E.7: Potential Changes to Energy suppliers' Roles and Resources

Current position	Intermediary between energy producers and small-scale consumers.
Future position	Future roles: The future function of energy suppliers could possibly move towards becoming ISPs.

Independent Service Providers (ISPs)

Independent service providers are new actors in the electricity system. It is important to emphasise that ISPs refer to those of providing online trading platforms as well as technical infrastructure to the end-users to enable active participation in energy exchange. ISPs play a central role in realising the Plasma scenario. As mentioned in the previous section, ISPs would assume many roles depending on their relationships with the current market participants.

Table E.8: Potential Changes to Independent Service Providers' Roles and Resources

Current position	NA.
Future position	Future roles: Depending on the relationships between ISPs and other market participants, there are many roles that the ISPs would assume:. 1. ISPs provide online trading platforms for energy trading purpose. The access to this platform is built upon contractual agreements between ISPs and their customers. 2. For the balancing services, ISPs would require to manage and allocate resources available in the network in order to ensure balancing between energy supply and demand. 3. In the data management system, ISPs would assume a role for data managers. Such a role allows ISPs to manage and operate their own network. 4. ISPs also assume a role of energy suppliers to their members due to their contractual agreements with their customers Future resources: To assume such roles ISPs are required to have a wide variety of resources. In order to provide online trading platforms, there are required to have a profound knowledge in the business itself as well as the grid management.